metal treatment

Vol. 25 : No. 153 JUNE. 1958 Price 2/6

NOW I.C.I. OFFERS

electrically heated salt baths

The General Chemicals Division of I.C.I. has recently concluded an agreement with

AJAX ELECTRIC CO. LTD. of Philadelphia

the largest manufacturer of electrically heated salt baths in the world. As a result of this, a range of I.C.I. 'Cassel'/Ajax furnaces heated by electrodes or immersion heaters, suitable for carburising, "cyanide hardening", heat treatment, tempering, martempering, austempering etc., will shortly be available in Great Britain (and a number of overseas territories).

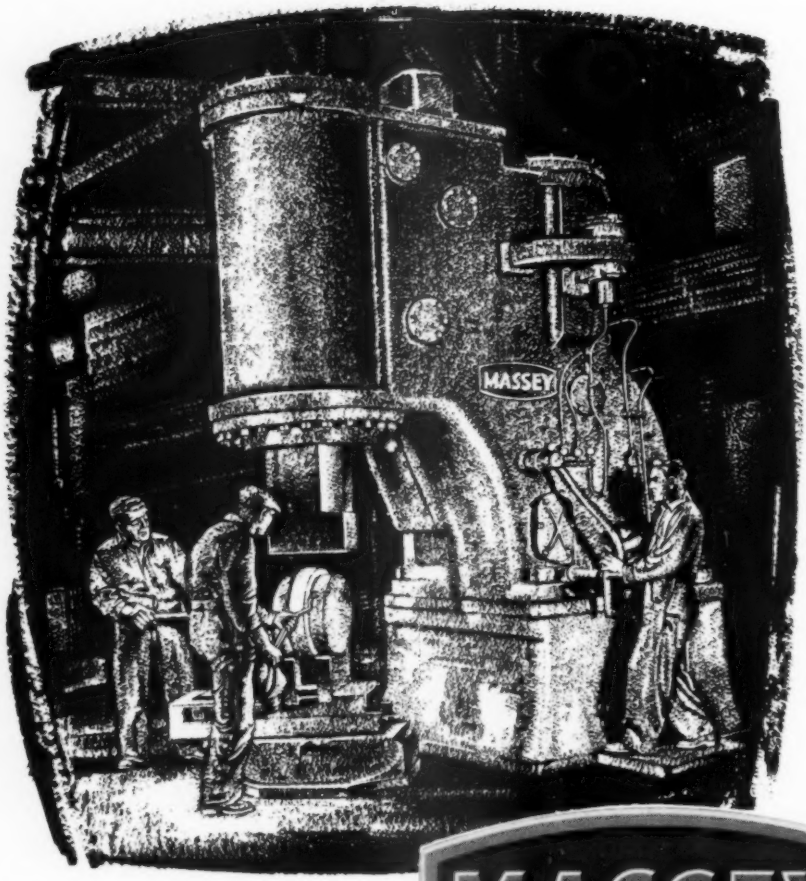
These electrically heated furnaces have the special advantage of extremely long pot life, of particular value in fully automatic salt bath plants.

The 'Cassel'/Ajax furnace is a notable addition to the wide I.C.I. range of gas- and oil-fired furnaces that have proved so successful over many years.

For fuller information, write now to:

IMPERIAL CHEMICAL INDUSTRIES LIMITED · LONDON, S.W.1

CC184



40 cwt. hammer, John Wilkes Sons & Mapplebeck Ltd.

MASSEY

cut costs with . . .

Massey electrically driven pneumatic power hammers are available in a range of sizes from 1 cwt. to 40 cwt. capacity. They are as powerful and as easily controlled as the best steam hammers and will strike definite controllable single blows in addition to a wide range of automatic blows. By virtue of low running and servicing costs these hammers show considerable economy in large or small forges.

Massey designs include:—
Steam and Compressed Air Hammers, Pneumatic Power Hammers, Friction Drop Hammers, Double-acting Steam and Compressed Air Drop Hammers, Forging Presses, Trimming Presses, Tyre Fixing Rolls

B. & S. MASSEY LTD. OPENSHAW · MANCHESTER · ENGLAND

MAKERS OF THE WORLD'S GREATEST RANGE OF FORGING PLANT

They rely on **WILD BARFIELD** *Gas Carburising at*

Holman Bros. Ltd.

Precise control of depth and type of case is afforded by both Wild-Barfield gas carburising processes — the "P.T.G." and "Carbodrip" drip feed. By these methods carburising proceeds at almost the maximum theoretical rate. We will be glad to send you full details on request.

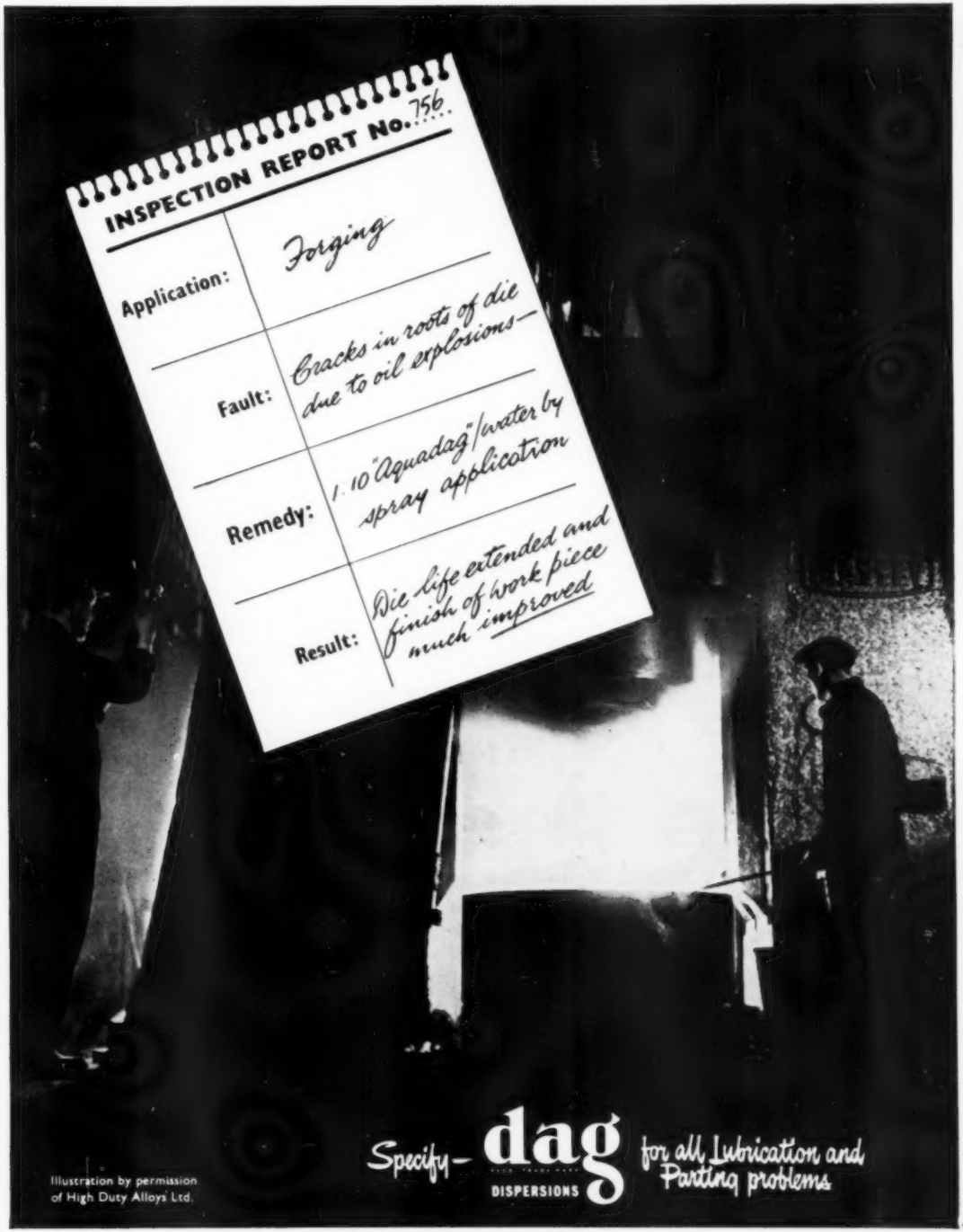
Components used in the Holman Silver Three Handril have to be really tough. The Wild-Barfield "Carbodrip" Drip Feed Gas Carburising equipment, shown above, is used in their manufacture.

FOR *ALL* HEAT-TREATMENT PURPOSES

WILD-BARFIELD ELECTRIC FURNACES LIMITED

ELECFURN WORKS, OTTERSPOOL WAY, WATFORD BY-PASS, WATFORD, HERTS. Telephone: Watford 6091 (8 lines)

WB 57


INSPECTION REPORT No. 756
Application: Forging
Fault: Cracks in roots of die due to oil explosions—
Remedy: 1:10 "Aquadag"/water by spray application
Result: Die life extended and finish of work piece much improved
Illustration by permission of High Duty Alloys Ltd.
Specify— dag DISPERSIONS for all Lubrication and Parting problems

ACHESON COLLOIDS LIMITED · PRINCE ROCK · PLYMOUTH · DEVON · TELEPHONE: PLYMOUTH 66351

Cold impact extrusion

... the fastest metal-forming technique

Cold impact extrusion is a fast and economical method of producing hollow containers and solid shapes in aluminium and certain other non-ferrous materials.

Save cost and material

Many components now used in industry and produced from these materials by a variety of other processes, lend themselves to production by impact extrusion with consequent saving in cost and material. This cold forming process induces added strength in parts by utilising the grain flow, and produces a smooth and flawless finish.

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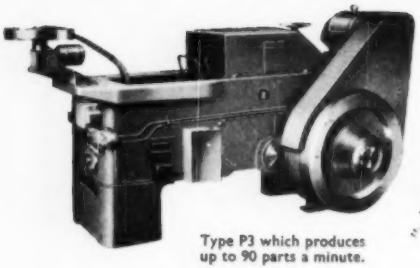
Herlan presses are available with production rating from 35 to 95 parts a minute. Extrusions up to 4¼" diameter (aluminium) at a wall thickness of 0·011" and maximum length of 12¾" may be obtained from these versatile machines.

Automatic operation

The presses are entirely automatic, and after loading, feed, form, strip-off and eject in rapid sequence. The horizontal working stroke is smooth and the shockless operation promotes long tool life.



Type P3 which produces up to 90 parts a minute.

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EXTRUSION PRESSES

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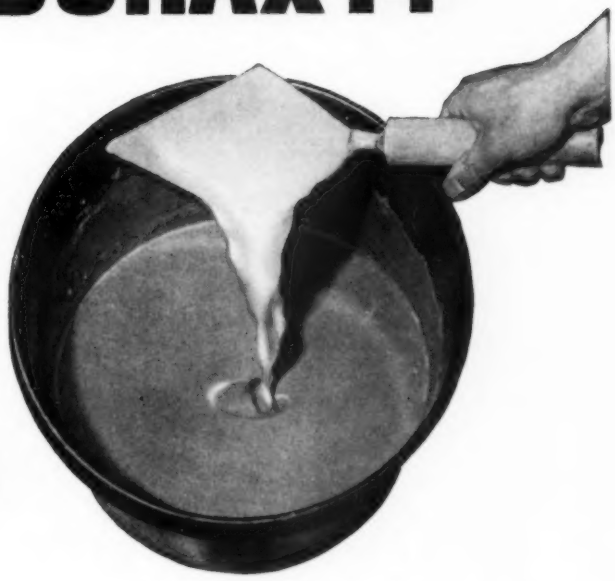
Ready-to-use REFRACTORY CEMENT!

Plastic

DURAX '14'

The *Time-Saving Way* to obtain THIN STRONG JOINTS



A ready-to-use jointing mortar supplied in a smooth plastic condition, which may be applied with a trowel in the normal way, or used for "dip and rub" joints. Durax No. 14 is an aluminous refractory cement which contains a high proportion of pre-calcined material to control shrinkage and produce thin, solid joints which set hard without the application of heat. These joints are as impermeable to the action of the furnaces gases as the bricks themselves, resulting in reduced cool air infiltration and improved thermal efficiency.
Designed for use between 1000°C and 1650°C. For lower temperatures Durax No. 4 is recommended.

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FOR BRIGHT ANNEALING 3 TON CHARGES OF COPPER STRIP

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G.E.C. 275kW, vertical cylindrical furnace installed at the Kynock Works of I.C.I. Metals Division

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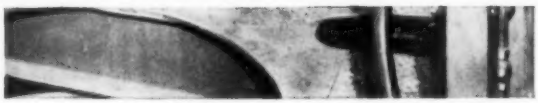
G.E.C. FURNACES · HIGH FREQUENCY · INFRA-RED



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make installation

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and cheaper

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TRI-MOR Standard Castable
A medium texture refractory having negligible shrinkage up to 1,350°C. Suitable for casting special shapes or for monolithic structures. Limiting service temperature 1,350°C.

TRI-MOR High Strength Castable
A similar refractory to Tri-Mor Standard Castable, but specially developed to have very high mechanical strength over the lower temperature range. Maximum service temperature 1,250°C.

TRI-MOR High Temperature Castable
Suitable for face temperatures up to 1,600°C; has an extremely high resistance to thermal shock; used for cast in situ monolithic structures and for pre-cast refractory shapes; can be applied with a cement gun.

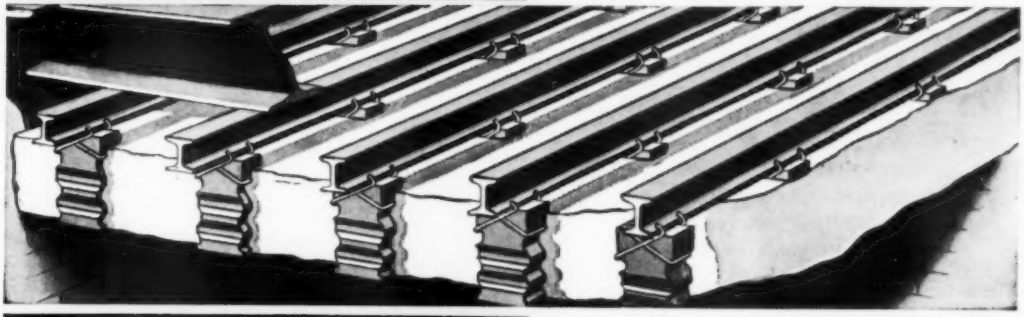
TRI-MOR High Temperature Mouldable
A plastic refractory for use up to 1,650°C : low shrinkage and a high resistance to spalling. Supplied mixed to the correct consistency for installation.

TRI-MOR Dense "Guncrete"
A hydraulic setting refractory with a maximum service temperature of 1,300°C. It has a high resistance to abrasion. Designed for application by cement gun, but can be trowelled.

TRI-MOR Insulating Castable
An insulating castable for maximum service temperatures of 1,200°C; low thermal conductivity is its main feature.

TRI-MOR Insulating "Guncrete"
Similar to Tri-Mor Insulating Castable but for application by cement gun.

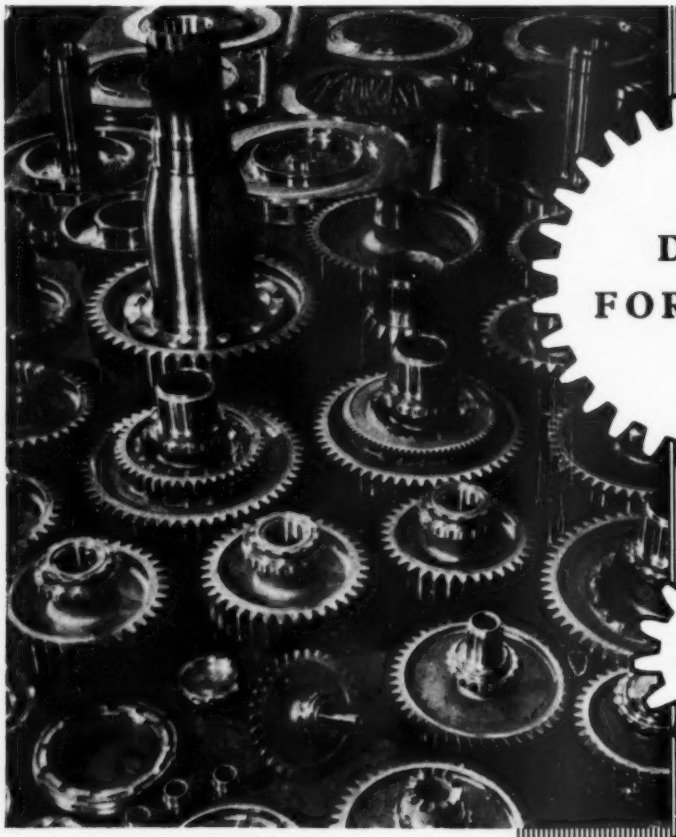
Full details of each grade are available on request.



Soaking pit cover in Tri-mor High Temperature Castable with ceramic keys.

MORGAN Refractories Ltd

For further information write to: MORGAN REFRACTORIES LTD NESTON, WIRRAL, CHESHIRE. TEL: NESTON 1406 MR 136



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THE FIRTH-DERIHON STAMPINGS LIMITED

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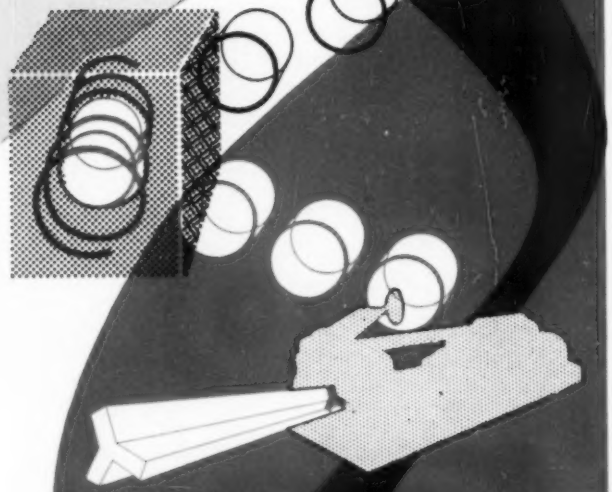

Progressive managements specify Birlec induction heating plant for billet heating applications including forging, upsetting, extrusion and rolling. Not only are high outputs obtained with consistent quality but the method saves floorspace and, due to absence of scaling, extends die-life. Lending themselves to mechanical work-handling, Birlec induction heaters also promote more flexible programming of work.

Induction Heating of Billets

There are no heat losses due to stand-by and heating-up periods, and temperatures are accurately regulated. Fewer operatives are required, their working conditions are improved, productivity is increased and overall production costs may be substantially reduced.

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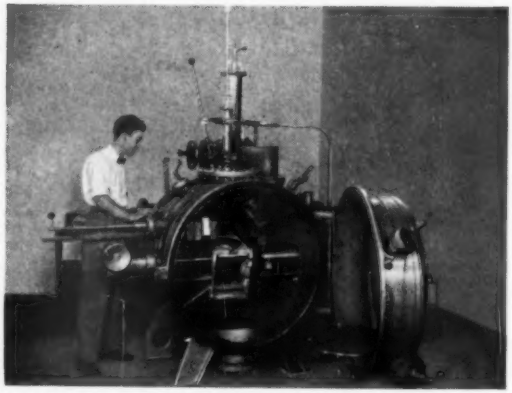
The experience of the National Research Corporation, who have built and operated more high vacuum furnaces than any other company in the world, and the facilities in Britain of Wild-Barfield combine to offer unsurpassed vacuum melting equipment.

Both arc and induction furnaces are available, the former with consumable or non-consumable electrodes, cold mould or skull type. Induction heated equipments include the N.R.C. patented semicontinuous vacuum melting furnaces.



Model 2555 Vacuum Induction Furnace with melting capacity of 50 pounds of steel. Other standard furnaces have capacities of 12 to 3,000 pounds.

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Melting, Alloying, and Purifying; Centrifugal, Ingot, Shape, and Investment Casting; Sintering, Brazing, Degassing and Heat-Treating.

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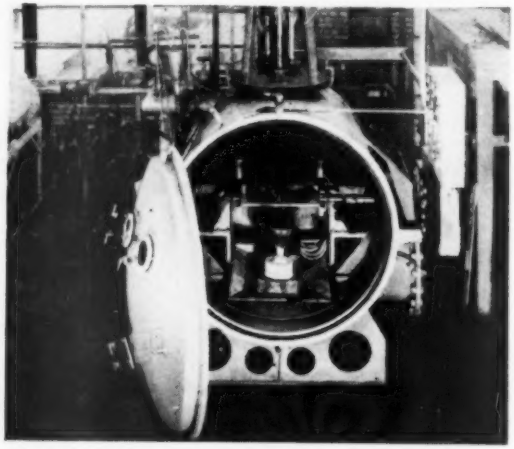
Melting and alloying high temperature or reactive metals such as niobium, tantalum, cobalt, zirconium and titanium.



Model 2705 Non-Consumable Arc Skull Furnace with a capacity of 53 pounds of titanium. Other standard vacuum arc furnaces have capacities of 8 to 10,000 pounds of titanium.

OTHER VACUUM EQUIPMENTS

- **Vacuum Fusion Gas Analyser**
- **Hydrogen Analyser**
- **Resistance Furnaces**
- **High Vacuum Diffusion Pumps**

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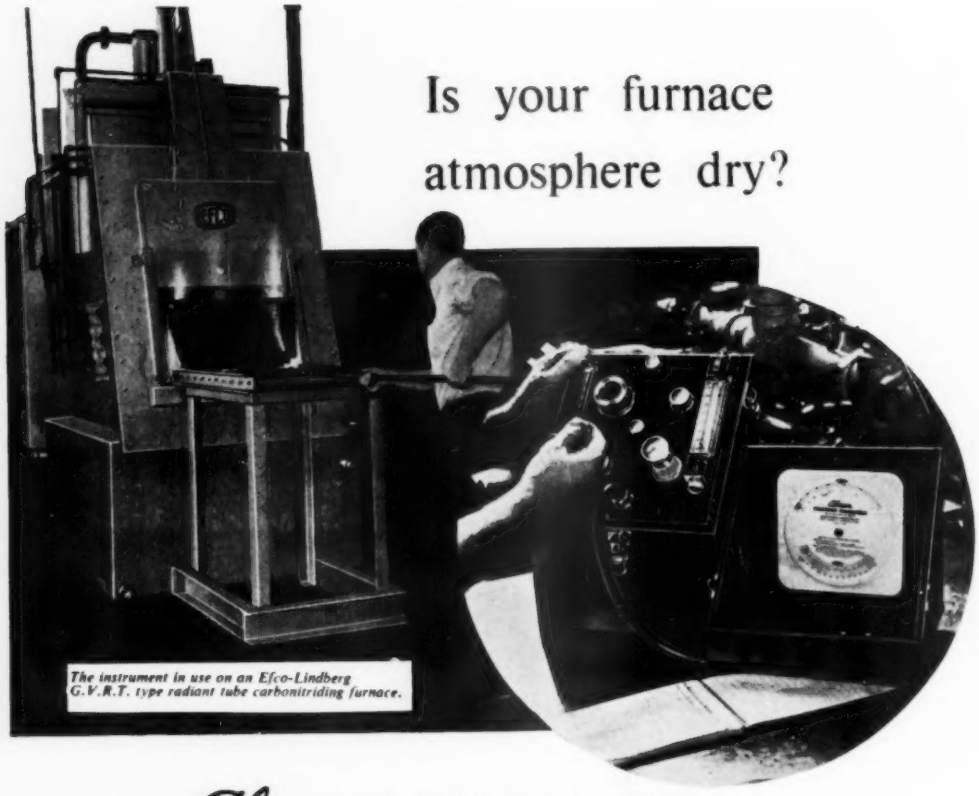

Is your furnace atmosphere dry?

The instrument in use on an Efco-Lindberg G.V.R.T. type radiant tube carbonitriding furnace.

. . . the *Alnor* DEWPOINTER *tells you instantly, accurately*

Where precision control of furnace atmosphere is essential the dew point should be checked accurately against the gas analysis. This can be done quickly and exactly with laboratory precision by non-technical personnel using the Alnor Dewpointer. The complicated physics of dew point determination are reduced to a few simple, mechanical steps.

There is no guesswork as when trying to observe condensation on a polished surface. The dew or fog is seen suspended in an enclosed chamber under conditions that can be controlled or reproduced again and again. Self-contained, readily portable, requiring no external coolant or auxiliary apparatus, the Alnor Dewpointer operates on A.C. mains or on an enclosed battery. It can be used anywhere, at the furnace or gas generator, easily taken about, easily used.

Eliminates guesswork

The gas sample is held in an enclosed observation chamber at a pressure above atmospheric by an efficient hand pump. The fog and its vanishing point are seen clearly in a cone of light.

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Associated with Electric Furnace Co. Ltd., and Electro-Chemical Engineering Co. Ltd.

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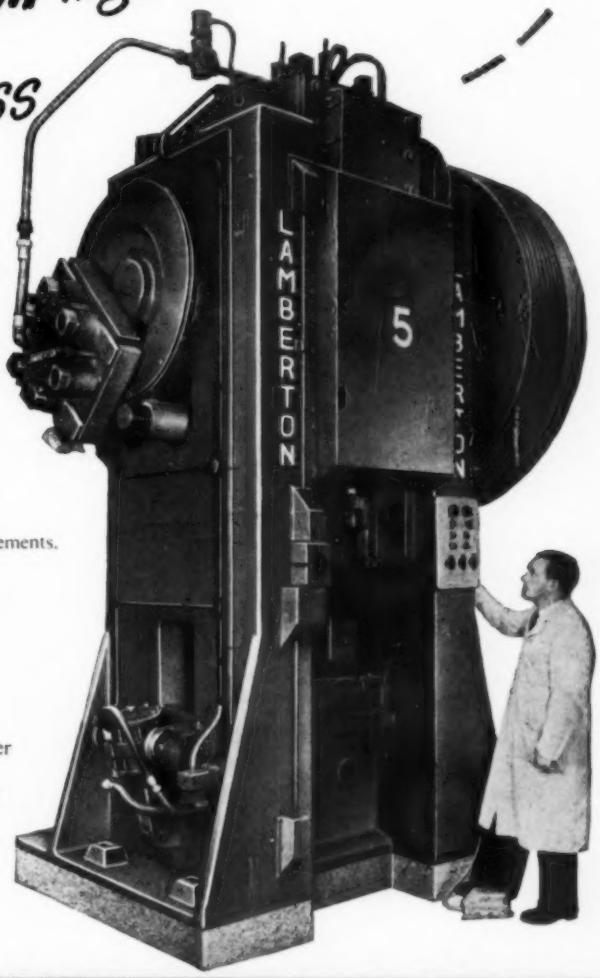
4 outstanding features of the Lamberton high speed vertical forging press



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Our own design giving excellent performance under severest conditions.

Top and bottom ejectors
air operated, adjustable to suit all requirements.

Operation of air ejectors
can be limited to every second or third stroke as required.

Calibrated table adjustment
ensures accurate die setting.

The Lamberton Press produces accurate forgings at high speed under rigorous production conditions, and requires minimum maintenance for safe, reliable operation.

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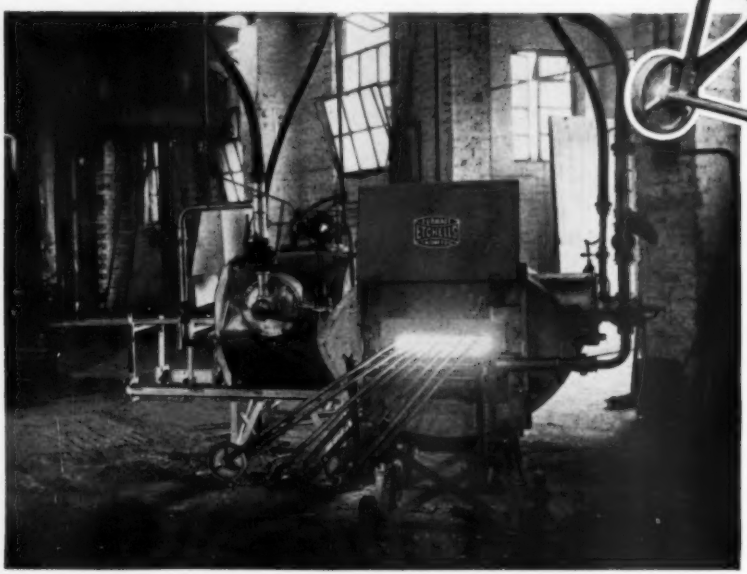

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IMPROVED OPERATING CONDITIONS.
LOWER RUNNING COSTS.
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LESS WASTAGE, AND INCREASED OUTPUT.

Oil-fired Slot Type Forge Furnaces

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'SHEARMASTER' BILLET SHEAR

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STRIPPING AND SETTING PRESS

Wilkins & Mitchell Forgemaster High Speed Forging Press, 1,500 tons capacity, and Clipping and Setting Press in production on precision forgings for Messrs. Garringtons, Bromsgrove.

600 ton capacity Stripping and Setting Presses in the Works of Messrs. Clydesdale Stamping Co. Ltd., Netherton.

Wilkins & Mitchell Stripping and Setting Presses make multiple operations in line-flow production a practical proposition. This increases the productive capacity of both drop hammer and forging press and ensures:

- increased output
- closer tolerance forgings
- reduced component cost

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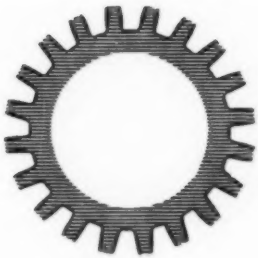

Gear Hardening is one of the several production line operations for which Induction Heating is admirably suited. The right way to tackle the problem is to ask Delapena to put their Applications Department at your disposal.

Getting your teeth into the problem

They will show, with particular reference to *your* manufacturing needs, how costs can be reduced by the elimination of grinding operations; how tooth profile can be finally hardened with the minimum of 'shape change'; and how a quieter and longer-lasting gear results.

To problems of repeat Hardening, Soldering and Brazing, Delapena Induction Heating Equipment can provide an economical answer.

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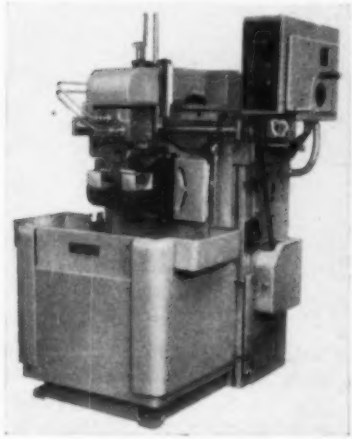
This equipment, for example, is fully automatic and handles gears within a range of 1½" to 26" diameter, 2 to 10 diametral pitch, face widths up to 8" and helical gears up to 30°.



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Dependability and Quality in Special purpose Alloy and Carbon Steels

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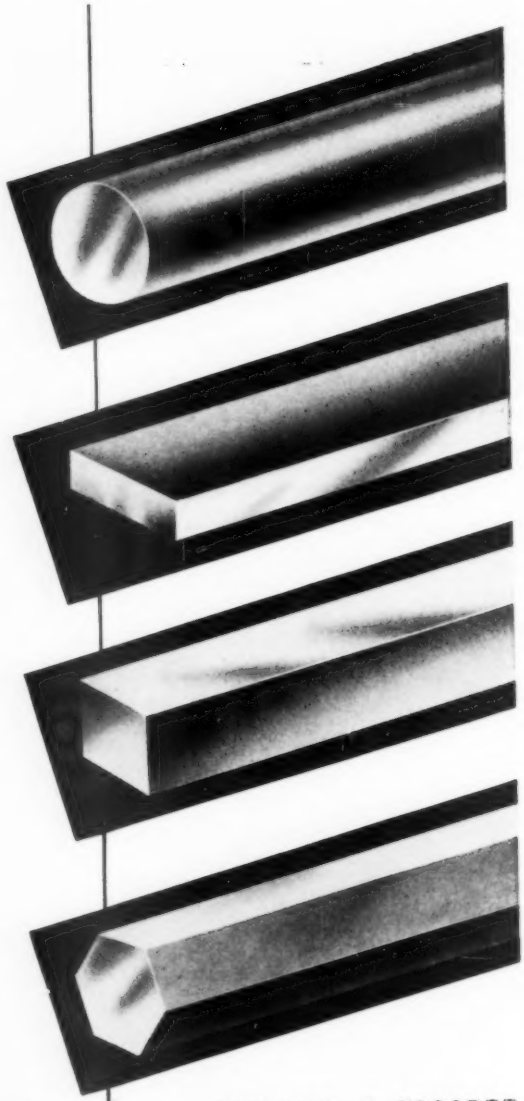

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With push button Programme Control

Producing heavy pipe flanges **12" dia. bore x 19" o/d.**, from billets, in one heat and three blows.

The press is equipped with push button programme control to give blows of different strength automatically for one operating cycle.

Maximum nett energy rendered is approx. 195,000 ft./lb.

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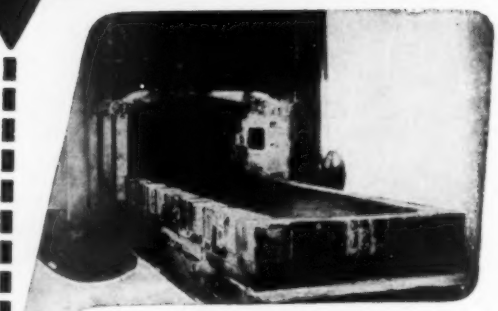
BOGIE TOPS

Examples of another of the many uses for

REFRACTORY CONCRETE

Atlas Steel Foundry. Bogie for mould drying stove, topped with Refractory Concrete. Bogie is 25ft. long and 10ft. wide, the topping being 6in. thick. The door shown is lined with Ciment Fondu insulating concrete.



Wm. Jessop & Sons Ltd. Bogie is 15ft. long by 5ft. wide topped by 6½in. of Refractory Concrete.

—Its monolithic construction eliminates troubles due to displacement of bricks

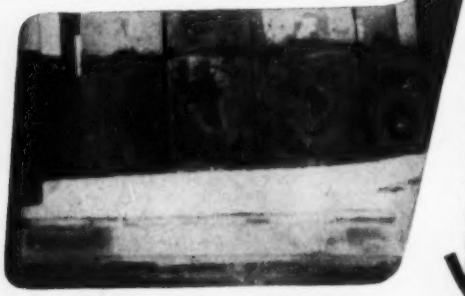
—It will withstand severe thermal shock without spalling

—It is ready for use and of great strength and hardness in 24 hours

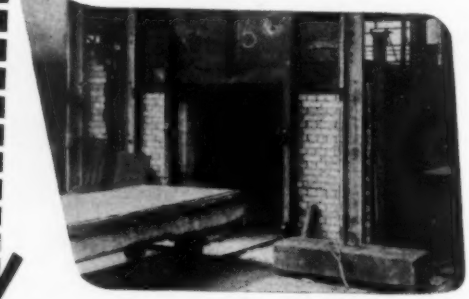
—It has no appreciable drying shrinkage or after-contraction

—It is stable under load up to 1300°C. (2400°F.)

Bogie used at large Northern Foundry, in gas-fired tunnel oven, for annealing maleable iron at 1050° C. Bogie is 7ft. by 7ft. and the Refractory Concrete is 12in. thick.



Crossley Bros. Ltd. Bogie for gas-fired annealing oven operating at 650° C. The door is also lined with Refractory Concrete.



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the adaptable Refractory material made with crushed firebrick and CIMENT FONDU

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ALUMINOUS CEMENT

The Cement for Industry
FOR SPEED · STRENGTH RESISTANCE · REFRACTORINESS

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(Over 70% Al_2O_3)

IRON COMPOUNDS & SILICA LESS THAN 1%

SECAR

250

Registered Trade Mark

Bonded with appropriate aggregate this cement provides Super-duty Castable Refractory Concrete for service temperatures up to 1,800°C (3,300°F) Refractory Concrete free from Iron Compounds & Silica is now possible for the first time.

A REFRACTORY CONCRETE FOR ANY PURPOSE

SECAR 250

is a product of

Lafarge Aluminous Cement Co. Ltd.

Manufacturers of

CIMENT FONDU

Read Trade Mark

ALUMINOUS CEMENT

BECAUSE

Almost the entire Refractory field can be covered by Refractory Concretes based on SECAR 250 or CIMENT FONDU

SECAR 250 concretes have all the well known properties of Ciment Fondu concretes

PLUS

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- **HIGH REFRACTORINESS**
- **HIGH SLAG RESISTANCE**
- **HIGH COLD STRENGTH**
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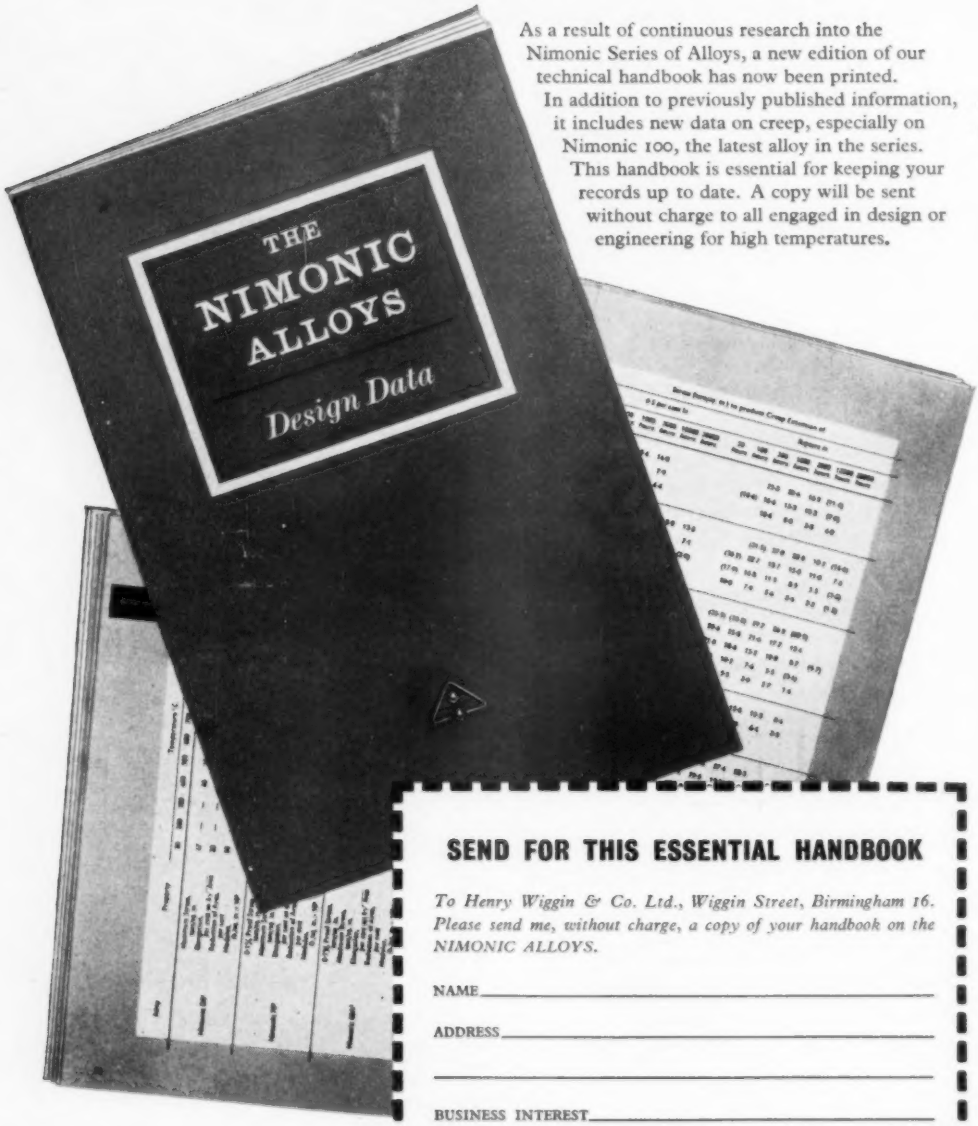

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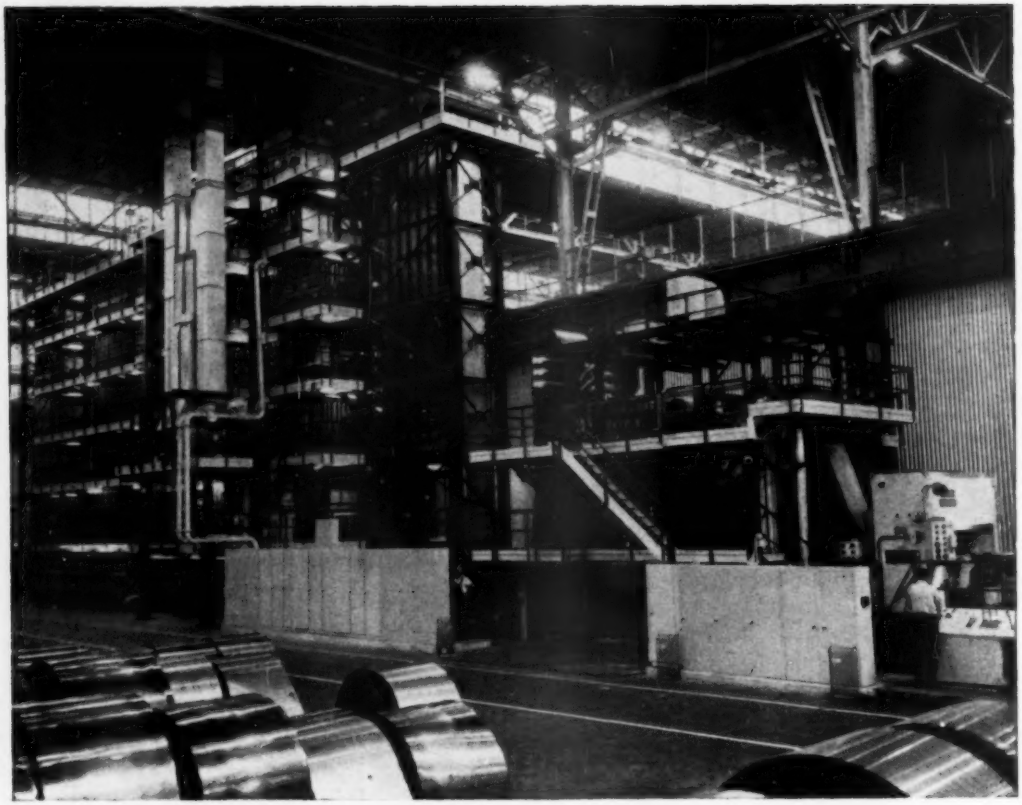

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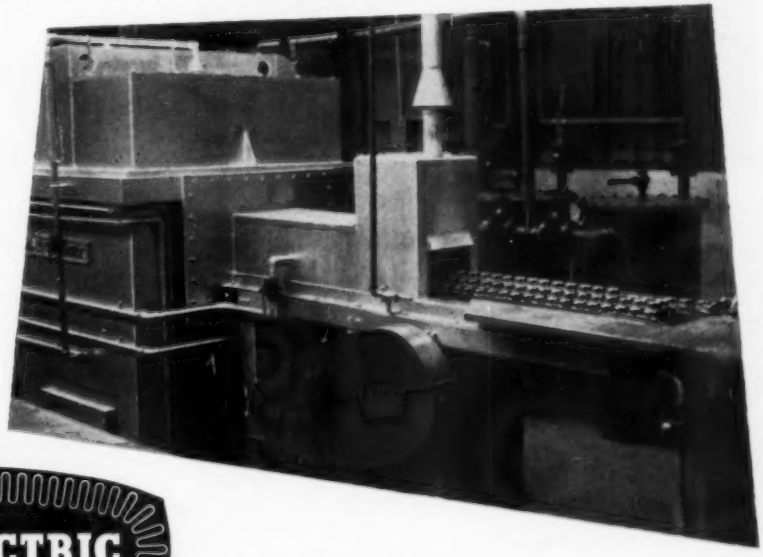

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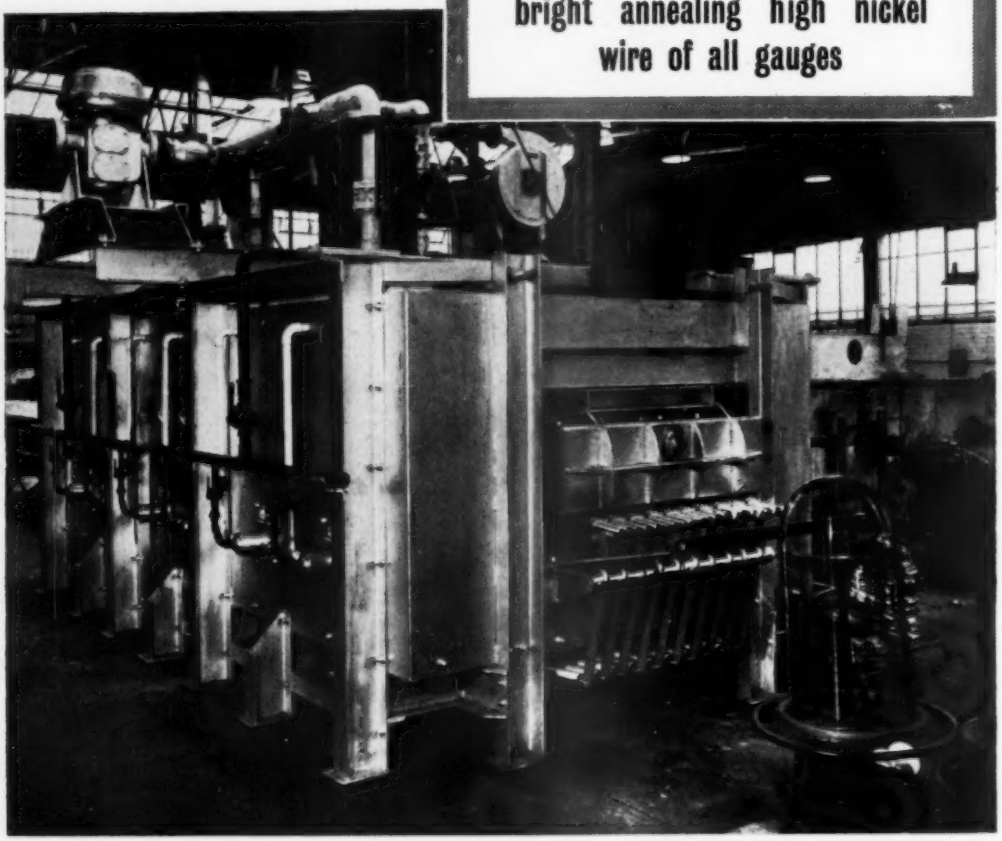

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June 1958

Vol 25, No 153

Metal treatment

and Drop Forging

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Official organ of the NATIONAL ASSOCIATION OF DROP FORGERS AND STAMPERS

President J. H. SWAIN

Director A. L. STUART TODD, M A, J P

Grove Hill House, 245 Grove Lane
Handsworth, Birmingham 20
Telephone NORthern 3311-3
Telegrams Asdroforge, Birmingham

Published on the 15th of each month by

INDUSTRIAL NEWSPAPERS LIMITED

John Adam House
17-19 John Adam Street
Adelphi, London W C 2

Telephone TRAfalgar 6171 (10 lines)
Telegrams Zacatecas, Rand, London

Subscription Terms Home and Overseas 30s per annum prepayable
Single copies 2s 6d (2s 10d post free)

CONTENTS

This journal is devoted to metals—ferrous and non-ferrous—their manufacture, properties, heat treatment, manipulation. testing and protection, with research work and development in all these fields

219 **Packed in aluminium**

221 **Controlled atmospheres for metallurgical processes: Part I** I. L. S. GOLDING
Heat-treatment processes which are best performed in neutral or active reducing atmospheres are described, and the underlying chemical reactions discussed

227 **Radioisotopes and their uses in metallurgy** F. SCOTT, B SC (Lond), F R I C
A discussion on radioisotopes and their metallurgical uses given at the advanced short course on laboratory arts held at the Wolverhampton and Staffordshire College of Technology

233 **Work handling for multi-spindle automatics**
Some of the work-handling devices developed to overcome delays in loading and re-starting chucking automatics are detailed

236 **Chemical surface protection of light metals** DR ENG A. POLLACK
Methods of protecting aluminium and magnesium alloys from corrosion

239 **The heat treatment of En steels** F. C. BIRD, A I M, and G. R. MORTON, F I M, A M I M M, M I B F
Heat treatments of typical En steels are described in relation to the transformation diagrams and hardenability curves. One of the series of heat-treatment lectures at the Wolverhampton and Staffordshire College of Technology

249 **Induction heating for forging** P. E. HAMMARLUND, and Y. SUNDBERG
A brief account of the theory of induction heating, with particular reference to its advantages in forge shops

254 **New French iron and steel research centre**
A description of the new pilot-plant at Maizières-lès-Metz, recently opened by IRSID

258 **Heat exchanger for nuclear power station**

259 **News** 261 **People** 263 **New plant**

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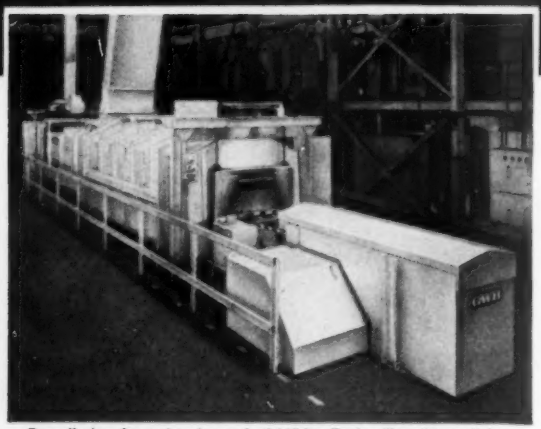

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Packed in aluminium

THE importance of aluminium as a metal for making various kinds of packs and packages is illustrated by the Symposium on Aluminium in Packaging which was held in London this month under the aegis of the Aluminium Development Association. This was a one-day conference divided into two sessions at which a total of eight papers were presented by managers, metallurgists and designers, covering most of the technical aspects of this subject.

Aluminium became a significant commercial metal some seventy years ago when Hall, in the U S A, discovered the electrolytic method of producing it from bauxite dissolved in a bath of molten cryolite. Before this time it was so expensive that, while its excellent properties of corrosion resistance and lightness were recognized, it remained something of a curiosity. So much so that the French Emperor Napoleon III once entertained his guests by having dinner served on plates of aluminium! Today the annual world production of aluminium exceeds 4 million tons and over the past six years has been increasing at the rate of some 50,000 short tons per annum. This rate of increase in production outstrips that of all other metals, including steel and copper. More aluminium is now available than is completely taken up by present fields of application.

In the U K in 1950 some 16,000 tons of aluminium went into the packaging industry; in 1957 this had risen to a figure of some 30,000 tons. This represents over 10% of the total usage of the metal. In general, however, the market is by no means saturated, in fact an O E E C report on the Light Metals Industry published in 1957 has predicted that the use of aluminium in Europe is likely to increase for the following reasons: (1) there are continual improvements in production and fabricating methods; (2) the popularity of aluminium with the public is increasing; (3) new outlets are constantly being developed; and (4) there are different degrees of penetration into certain markets in various countries.

In his paper presented at Symposium Mr. J. C. Bailey, the assistant technical director of A D A, pointed out that aluminium foil began to displace earlier metallic foils such as tin, lead and tin/lead alloy in the early 1930s and rapidly gained ground because it was superior technically, less costly and lighter in weight. The lower weight was an important consideration, at least in the U S A, as a direct saving resulted at once from reduced transport costs.

The introduction of plastics films occurred after aluminium had gained a strong foothold as a wrapping material. Plastics have been viewed by some as a rival to aluminium foil for wrapping purposes, and examples can doubtless be quoted of commodities packed in plastics that would otherwise be wrapped in foil, but it must be accepted by any materials supplier in this technological age that many materials are available to the user of packages and that no one material is likely ever to dominate the packaging field in the future.

Selection is largely based on three major considerations—technical suitability, appearance and cost. From the technical aspect the outstanding characteristic of aluminium foil is its high resistance to the passage of water vapour and liquids. It is virtually an im-

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Controlled atmospheres

for metallurgical processes: Part I

I. L. S. GOLDING

Heat-treatment processes which are best performed in neutral or active reducing atmospheres are described, and the underlying chemical reactions discussed. In the second and concluding part of this article, which will be given next month, present-day processes and plant for generating special atmospheres will be surveyed. The author is with Incandescent Heat Co Ltd

PACKAGED PLANT is now available for generating nitrogen, carbon monoxide, carbon dioxide, hydrogen, and mixtures of these and other gases, which find wide and varied use in heat-treatment processes. Metal properties may be profoundly influenced by the gas composition, for this can serve to protect a metal surface against attack by atmospheric oxygen or react in some way with the metal to improve its chemical, physical, or mechanical properties. Casehardening, annealing, normalizing, tempering, spheroidizing, cleaning, and gas pickling are examples of heat treatment processes for steel which require or are best performed in a neutral or active reducing atmosphere. In non-ferrous metallurgy bright brazing, annealing of copper and brass, and sintering of powdered metals are but a few of a wide range of possible applications.

General discussion

Before discussing any of these processes in detail some mention must be made of the underlying chemical reactions of various gaseous constituents with each other and with steel at elevated temperatures.

(1) $Fe + H_2O \rightleftharpoons FeO + H_2$
(2) $Fe + CO_2 \rightleftharpoons FeO + CO$
(3) $Fe_3C + CO_2 \rightleftharpoons 3Fe + 2CO$
(4) $Fe_3C + H_2O \rightleftharpoons 3Fe + CO + H_2$
(5) $3Fe + CH_4 \rightleftharpoons Fe_3C + 2H_2$
(6) $CO + H_2O \rightleftharpoons CO_2 + H_2$
(7) $CH_4 \rightleftharpoons C + 2H_2$
(8) $CH_4 + CO_2 \rightleftharpoons 2CO + 2H_2$
(9) $C + CO_2 \rightleftharpoons 2CO$

All the above reactions are reversible and will proceed to a state of equilibrium under normal conditions. The concentration of each constituent is governed by its partial pressure at a given temperature and may be calculated or found by reference to some of the excellent equilibrium diagrams that have been published.[1]

Briefly, reactions (1) to (4) show that if water vapour and carbon dioxide are present in the atmosphere to an appreciable extent, then oxidation or decarbonization of steel will occur. From this we may conclude that as a general rule, the lower the concentration of these gases, the better will be the results obtained in most steel heat-treatment processes. Many controlled atmosphere plants are therefore designed to generate a gas in which these two constituents are in very low concentrations, or virtually absent. Reaction (3) shows the importance of having an excess of carbon monoxide above that required for equilibrium with carbon dioxide at a given temperature, thereby preventing the reaction from proceeding to the right, and causing decarburization.

The provision of extra carbon at the steel surface by the action of methane or other hydrocarbons is shown in reaction (5). Equilibrium favours reaction to the right at temperatures above about 800°C, and the presence of iron at the surface is an active catalyst in promoting the dissociation of methane. Inter-reactions between various constituents are frequently encountered in controlled atmospheres, and equations (6) to (8) cover the most important of these. A further reaction (9) is useful in understanding the mechanism of some types of generator where carbon dioxide concentrations are reduced by passing the gas through a strongly heated charcoal bed. The importance of these reactions, especially those governing gaseous constituents, becomes clearer where it is considered that although one gaseous compound may adversely affect the surface of a piece of steel, combination with another constituent can counteract or even reverse this process. For example, carbon dioxide is normally

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permeable material. Furthermore, this water-vapour barrier can be provided at minimum cost.

Most organic or plastics wraps have much lower resistance to the passage of water vapour, their permeability in some cases being several hundred times greater. Plain aluminium foil is of very low permeability and is the least expensive material; its cost is still the minimum for the high degree of resistance to water vapour transmission that it provides. Despite the virtues of other wrapping materials, they are at present more expensive than aluminium foil for the same effectiveness as water-vapour barriers. It is this quality of providing a first-class water-vapour barrier at minimum cost, coupled with a brilliant appearance, that gives strength to the economic case for aluminium foil and laminates.

The collapsible tube is one of the commonest methods of packaging, as a visit to any chemist's shop will immediately show, and early collapsible tubes were made from the very soft metals, tin lead and tin-coated lead. Improvements in the impact-extrusion process, however, coupled with the growing output of aluminium, has led to its gaining a dominant position in this field as it has done in the form of foil. Furthermore, there is often no other material that can be used for certain packages in the form of impact extrusions, *e.g.* large collapsible tubes for foodstuffs and other products.

In the field of rigid containers, more generally referred to perhaps as 'tin cans,' aluminium has already gained an important foothold. In 1956 more than 3,000 tons of aluminium were used in Europe for rigid, hermetically-sealed containers, chiefly for canning food. This position has been reached gradually: wartime shortages of tinplate, particularly in Scandinavia and other European countries, stimulated technical enquiry and development leading to solution of most of the technical problems. In Great Britain the tinplate shortage of the post-war years led to the introduction of aluminium cans for certain commodities, since abandoned when the shortage ceased. This sequence of technical development, replacement for tinplate in short supply, and application to products for which tinplate could not be used, has given the needed scope for full-scale operation of new methods of aluminium can-making.

Any means of reducing costs in aluminium can production, said Mr. Bailey, are of economic significance, and there have been promising developments in Italy, U S A and, latterly, in the U K. In particular, the pilot aluminium-can lines now being operated in Europe and in the U S A indicate that a deeper entry of aluminium into the rigid can market is now imminent. Continuous processes have been developed for the conversion of ingot metal to slugs or circles for subsequent fabrication into containers. Molten metal is poured from the furnace on to a water-cooled casting wheel from which it emerges as hot strip metal. This is fed directly into hot rolls to reduce it to the desired thickness, and then goes through a blanking press where slugs or circles are formed; the scrap metal goes back into the furnace. A process of this sort, operated by a concern interested in manufacturing containers on a large scale, probably represents the ultimate step in the economical usage of aluminium. Another means of reducing overall costs that might be applied in suitable instances is the recovery of scrap metal from a once-used container and returning it for refining and re-processing.

Discussing questions of aesthetics Mr. Milner Gray, an industrial designer, said that looking at the possibilities of the extended use of aluminium in packaging from the point of view of its appeal to the consumer as well as to the manufacturer, he had no doubt that it could hold its present position in competition with other materials. Its wider acceptance, however, would depend very largely on the manufacturers' success in finding ways of keeping down costs.

For small hardening furnaces where the requirements of carburizing gas are proportionately small it is sometimes more convenient to produce the atmosphere in some way which does not involve the expense of an endothermic gas generator. Equipment of this type becomes expensive in relation to its size where an output of much below 200 cu ft/h is required, for no matter what the size, the same air to gas proportioning devices and instrumentation are required. Occasionally, it is possible to produce a reasonably satisfactory carburizing atmosphere by adding a small quantity of naphthalene, benzene, propane, or butane to raw town's gas, provided that it does not suffer frequent fluctuations in composition and the initial percentage of CO_2 is low. The work will not be of the same quality or uniformity as that produced in an atmosphere of known composition and possessing a definite carbon potential, but the method is sometimes useful. Vaporized hydrocarbons with a limited amount of air are also used with considerable success in quite a number of installations.

A more satisfactory method of generating atmospheres suitable for small-scale work without using special proportioning equipment is possible, and depends on the thermal or catalytic dissociation of methyl alcohol, or mixtures of methyl and isopropyl alcohols, benzene, and sometimes water. The mixture is either allowed to drip directly into the carburizing furnace or is vaporized and passed through a tube which may be set in the furnace brickwork or heated externally. Gas compositions are varied by altering the ratio of liquid ingredients, if more than one is used, or adjusting the reaction temperature, which is possible only where the tube is independently heated. A temperature of at least 800°C is required to ensure complete reaction. A typical analysis of the gas so produced is:

CO_2	0·2%
CO	22·4%
H_2..	66·4%
Hydrocarbons ..	11·0%

More information on these processes has been given by the author in other published work.[3]

[Incandescent Heat Co Ltd

1 *Pit-type gas carburizing furnace with quench tank in foreground*

Carbo-nitriding

The latest case-hardening process to be applied industrially in which a controlled atmosphere is involved is dry-cyaniding or carbo-nitriding, so-called because the steel surface absorbs both carbon and nitrogen simultaneously. It is, in fact, a combination of carburizing and nitriding, and is particularly useful for parts which require high resistance to frictional wear. Some controversy exists over the precise mechanism of this process, but practical experience has shown that at lower operating temperatures of the range 750 — 900°C, nitrogen is absorbed preferentially, whilst higher temperatures favour the absorption of carbon. Penetration proceeds at a much greater rate than in ordinary carburizing with the result that lower temperatures may be used for the same depth of case. Furnace wear and tear are consequently reduced and the work is less prone to distortion.

Atmospheres suitable for carbo-nitriding are produced by adding anyhydrous ammonia to almost any carburizing gas either just before or directly into the furnace chamber, where it dissociates on the work surface into nitrogen and hydrogen. Prepared in this way, nitrogen is very active and will rapidly penetrate a steel surface. The reason for this phenomenon is that ammonia dissociation proceeds initially according to the equation $NH_3 = N + 3H$, both gases being present in the atomic state for a fraction of a second. Atomic nitrogen and hydrogen are very reactive and quickly combine either with the iron or with another similar atom to form molecular nitrogen or hydrogen. High concentrations of hydrogen in the carbo-nitriding atmosphere tend to reduce surface hardness by reason of its very high rate of diffusion and the catalytic activity of iron. This is one disadvantage of using a straight hydrocarbon such as an oil spray and anhydrous ammonia for producing carbo-nitriding atmospheres.

oxidizing to steel, but by reaction with methane (reaction 8) carbon monoxide and hydrogen are formed, both of which are strongly reducing gases.

Case hardening

The introduction of additional carbon or nitrogen into the steel surface by chemical means may be accomplished by solid, liquid, or gas carburizing, or by carbo-nitriding. In each case the actual transfer of carbon takes place in the gas phase, and carburizing in a gas atmosphere has assumed very great importance in recent years. The chemical reactions involved in this process are (3) and (5) in the foregoing list. Gaseous products from these reactions may also play an important part in gas carburizing, the CO_2 produced in (3) must not exceed that required for equilibrium with CO at carburizing temperatures of 850—950°C. The concentrations are also affected by the quantity of CO originally present in the gas, and by the percentage of CH_4 available for reaction (8). Quite a small quantity of methane or other hydrocarbon is sufficient to maintain satisfactory carburizing conditions in a mixture of carbon monoxide and hydrogen. Generally 3 — 5% of propane is added to a carrier gas, where it dissociates with the formation of methane at about 650—700°C. Freedom from CO_2 and H_2O is essential as these are both strongly decarburizing to steel.

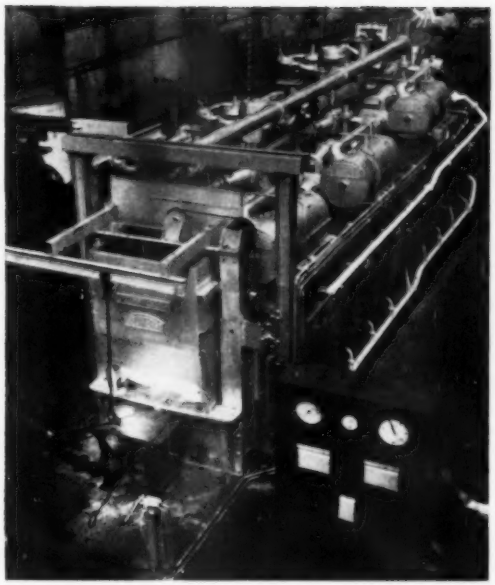
A variety of factors influence the carbon potential or the amount of carbon available for absorption into the steel surface; the analysis of the gas is the most important of these, but temperature and composition of the metal being carburized also affect the results. It is well known that at a given temperature carbon monoxide and carbon dioxide will co-exist in equilibrium concentrations, but if the temperature is altered, so are the percentages of each gas required to maintain equilibrium, an increase in temperature favouring lower CO_2 and *vice versa*. The quantity of carbon present in a steel is of importance in determining its reaction with a gas of known composition, for a gas can be carburizing to a 0·1% C steel neutral to 0·2% C steel, and decarburizing to 0·3% C steel, all at the same temperature.

Assuming that the steel chosen for case hardening is of known composition, two other factors determine the amount of carbon absorbed in a given time and very close control is required. These two factors are temperature and gas analysis. Dew point determinations are useful for they are related to the carbon potential of reacted gases.

Gas carburizing is carried out in either batch (fig 1) or continuous type furnaces, and is an ideal treatment for gears and other parts where a tough core protected by a hard wear-resistant shell is required. Case depth and hardness are varied to meet different requirements by controlling the temperature and time of carburizing and the hydrocarbon content of the gas. As already stated, iron is an active catalyst in promoting the dissociation of hydrocarbons, a process essential for rapid carburizing. High concentrations should be avoided, for if the rate of hydrocarbon decomposition exceeds the speed of carbon absorption, it promotes sooting with a consequent blanketing effect on the steel surface. When this occurs, the rate of carburizing is considerably reduced, suggesting that freshly produced carbon is more active and penetrates more rapidly than carbon which has been prepared for some time.

Very rapid gas carburizing and carbo-nitriding by induction heating has been reported by Assonov,[2] who states that processing times may be reduced to little more than one-tenth of that required by normal heating methods. Tests which we have recently made indicate the potential value of this process. Allowing for greater initial costs a plant utilizing this process would undoubtedly show considerable savings and lend itself particularly well to completely automatic control.

Several methods are available for the production of carburizing atmospheres. It is essential that these contain a carburizing constituent, generally a hydrocarbon of low molecular weight, although very high percentages of carbon monoxide will suffice in some instances. Frequently a carrier gas of carbon monoxide, hydrogen, and nitrogen is prepared and used as a diluent for the hydrocarbon. Water vapour and carbon dioxide must be excluded from the atmosphere as they are very active decarburizing gases. An endothermic or reacted gas generator using town gas or propane is one of the most convenient methods of preparing the atmosphere. Charcoal endothermic plants are also used extensively and the gas produced in this manner contains a very high percentage of carbon monoxide. Charcoal generators require regular attention and they are largely being superseded by the previously mentioned type of plant which, once set, requires only occasional inspection. The approximate gas composition, when generated from town gas and air, is 28% CO, 47% H_2, 1—2% CH_4, with the balance nitrogen. A higher percentage of hydrocarbon is required for rapid carburizing of high-carbon steels, and additions of propane, butane, benzene, or other suitable volatile hydrocarbons are made, either directly into the furnace chamber, or into the carrier gas. Carbon dioxide and water are not shown in the above list of constituents, since the reactions $CO_2 + C = 2\ CO$ and $C + H_2O = CO + H_2$, both proceed to the right at the operating temperature.



[Incandescent Heat Co Ltd

4 *Scale-free billet-heating furnace*

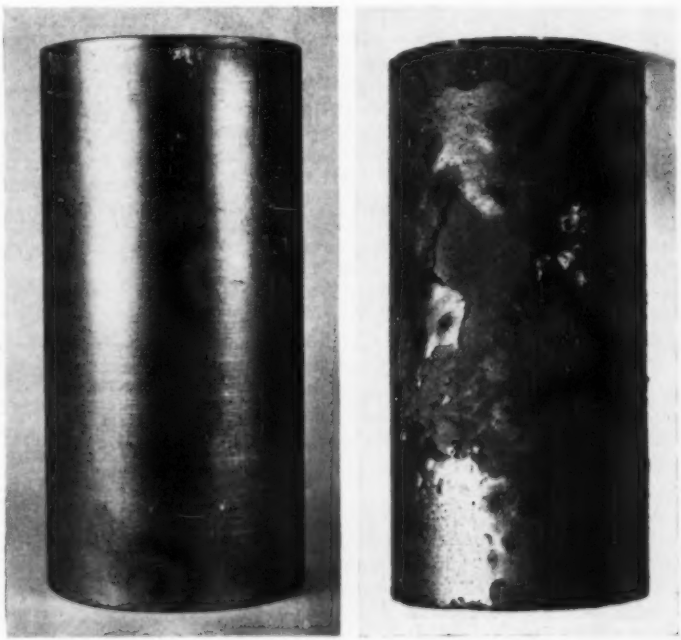
Billet heating

This is another application in which controlled atmospheres are finding increasing popularity, in spite of the argument that oxidation will occur as soon as the billet is removed from the furnace. Several important advantages do exist however, although they are not immediately apparent. Metal losses by scaling are reduced to a minimum by preventing oxidation whilst the billet is being heated. Wear on dies and rollers is considerably reduced, and should a delay or breakdown occur in some other part of the processing equipment, the furnace load may be maintained at temperature for an indefinite period. In ordinary products of combustion the billets would suffer severe oxidation if subjected to a prolonged soak.

Frequently billet-heating furnaces are run with a rich fuel-to-air mixture to maintain partially reducing conditions within the work chamber; the emission of a dense smoke is a characteristic of this practice. Where special atmospheres have been used, a separate piece of equipment for their generation was formerly required, and difficulties experienced in operating at temperatures in excess of 1,100°C. Recent developments, however, now enable a satisfactory atmosphere to be generated within the furnace, thus allowing much higher temperatures without the use of a muffle.

stainless steels can be annealed successfully in rich exothermic atmospheres but where bright work is required or decarburization has to be avoided, then an endothermic or pure gas atmosphere is often necessary.

The type of furnace used for annealing depends largely on individual requirements. Cold worked strip is frequently annealed in a box or bell-type furnace, whilst cold drawn tubes may well require a continuous roller hearth furnace. These can be heated by electric resistor elements, or gas-fired radiant tubes, where no contact between combustion products and work is possible. Both batch and continuous type furnaces are illustrated in figs 2 and 3.



5 (LEFT) *Billet heated in 'Equiverse' furnace* (RIGHT) *Billet heated in conventional furnace*

2 *Battery of lift-off furnaces showing bases, inner work cover furnaces, and work*

[*Incandescent Heat Co Ltd*

Annealing

Annealing is undoubtedly the most widely applied industrial heat-treatment process in which controlled atmospheres are used. The annealing or normalizing of low- and high-carbon steels, although requiring somewhat different atmosphere conditions, are essentially the same in that they relieve any internal stresses previously set up in the steel. Temperatures generally in the range of 650 — 850°C are used, although these depend both on the carbon content of the steel and the degree to which it has been worked.

The object of the controlled atmosphere is not to impart anything to the steel as in case-hardening, but to protect its surface against attack by oxygen or gaseous oxygen containing compounds, thereby maintaining or even improving the surface finish. For this reason the choice of suitable atmosphere compositions is much wider. It is a common belief that simple atmospheres, *i e* those containing only one or two constituents, are better than more complex mixtures as there is less chance of side reactions occurring. However, the majority of simple atmospheres, such as those derived from cracked or burnt ammonia, necessitate high capital outlay and are relatively expensive to run. Therefore, although there is some evidence to support the belief in simple atmospheres, it is a fact that by far the largest amount of annealing work is carried out in exothermic or burnt gas atmospheres, especially where low carbon steels are being processed.

Silicon steels for transformer laminations call for rather special treatment to prevent carbon pick-up or oxidation of silicon or iron, all of which can upset the desired magnetic properties. When a steel contains less than 0·005% carbon a trace of methane or a very small percentage of carbon monoxide is sufficient to cause carburization, especially at temperatures in excess of 800°C. In this case annealing must be performed in an atmosphere which is free from active carburizing or oxidizing constituents. Pure dry hydrogen or hydrogen/nitrogen mixtures derived from cracked ammonia have been used with success, but tend to be expensive. Interest is now centred on practically pure nitrogen produced by the complete reaction of town's gas or propane and air, which has proved successful and very much cheaper.

Many high carbon steels, tool steels, alloy steels and

[*Metalectric Furnaces Ltd*

3 *Continuous electric strip-annealing furnace*

Radioisotopes

and their uses in metallurgy

F. SCOTT, B Sc(Lond), F R I C

This discussion of radioisotopes and their metallurgical applications was given by the author at the advanced short course on Laboratory Arts in Metallurgy and Physics held last November at the Wolverhampton and Staffordshire College of Technology. Mr Scott is senior lecturer in chemistry at the College. It is hoped to publish other lectures given at the course in future issues

MORE THAN FORTY YEARS have passed since radioactive elements were first used as indicators in various investigations by G. Hevesy and F. Paneth.[1] The early workers in the field depended upon the naturally occurring radioactive elements and so their experiments had to be confined to the heavier elements like uranium, thorium, lead and bismuth which have unstable or radioactive isotopes.

After the discovery of artificial radioactivity by I. Curie and F. Joliot[2] in 1934 and more especially since the establishment of atomic reactors or piles, the availability and demand of radioisotopes of many elements have grown, not only in this country but throughout the world. The rate of consignments of radioactive sources from the Isotope Division, Harwell and the Radiochemical Centre, Amersham, has reached a figure of over 25,000 a year.

The atom

According to present-day theory, the atom consists of a comparatively large nucleus of protons and neutrons around which the much smaller electrons move in well defined orbits. Some characteristics of these fundamental particles are given in Table I.

TABLE I *Some data of fundamental particles*

	Actual mass a m u	Approx mass	Charge
Proton	1·00759	1	+1
Neutron	1·00898	1	Uncharged
Electron	0·00056	0	−1

The number of protons present in the nucleus of a particular atom is equal to its atomic number Z which, of course, determines the position of the element in the periodic classification and the number of orbital electrons. It is the orbital electrons and particularly the electrons in the outermost orbits, which determine the chemical and many of the physical properties of the elements. In the combustion of carbon, the electrons of the carbon and oxygen atoms merely regroup themselves to form the carbon dioxide molecule, and for each atom of carbon burnt 4 e v * of energy is liberated.

Radioactivity is a fundamental property of the nuclei of atoms. Thus the radioactive characteristics of a particular atom are independent of the chemical state of the atom. Once an atom is 'labelled' it will continue to be so no matter what the valency state is, until the activity decays away.

The presence of the neutrons in the nuclei of atoms do nothing more than add weight. In fact, isotopes are merely atoms of a particular element with a fixed value of Z, but having differing numbers of neutrons in the nucleus. Some elements have only one naturally occurring isotope while others may have as many as ten. A few of the common isotopes are listed in Table II.

TABLE II *Some common isotopes*

Element	No. of Protons or atomic no. (Z)	No. of Neutrons ($A-Z$)	Mass no. (A)	Symbol	Abundance (%)
Hydrogen	1	0	1	^{1}H	99·98
Deuterium or heavy hydrogen	1	1	2	^{2}D	0·02
Sodium	11	12	23	^{23}Na	100·00
Chlorine	17	18	35	^{35}Cl	75·4
	17	20	37	^{37}Cl	24·6
Copper	29	34	63	^{63}Cu	69·0
	29	36	65	^{65}Cu	31·0

All the isotopes listed in Table II are stable, for they do not undergo any spontaneous change with time. There are 274 stable isotopes known of the 90

*1 electron-volt = $4·82 \times 10^{-20}$ calories.

The ' Equiverse ' system recently announced by the Incandescent Heat Co Ltd has a work chamber in which town gas is partially burnt with preheated air, thereby maintaining an atmosphere which is non-oxidizing to the steel billets. After passing through the work chamber, partially burnt gases and additional air are completely burnt in regenerators. The direction of flow is reversed at short intervals, when the hot regenerator is used to preheat air for partial combustion. Fig 4 shows a furnace utilizing this principle. The rate and degree of decarburization of steels is very small under these conditions. Billets heated in a furnace of this type and subsequently protected from atmospheric oxidation whilst cooling, are virtually indistinguishable in appearance from an untreated specimen. Fig 5 shows two billets, one heated in a furnace using this system of firing and the other in a conventional furnace.

Descaling, metal cleaning and gas pickling

Specially prepared atmospheres offer a neat and very economical way of performing these operations. Gas pickling, or etching, is carried out in atmospheres where non-equilibrium conditions exist. Under such conditions iron becomes roughened due to its catalytic activity in promoting equilibrium of gas phase constituents and by reduction of surface oxide to spongy or porous iron. This process has been used to reduce drastically the time required for acid pickling and yet give more evenly etched articles prior to vitreous enamelling. Some success has been obtained in attempts to dispense completely with acid pickling prior to metal finishing. In general this is dependent on first adequately removing all grease and drawing compounds used during manufacture, so as to prevent carbon formation or deposition during processing. Suitable atmospheres for these operations are obtained from an exothermic gas generator using a low air/gas ratio. Claims that tighter hot galvanized coatings are obtained by gas pickling in an atmosphere containing 10—20% HCl have been made and confirmed by Pearson, Bullough and Canning.[4]

Batch or continuous type furnaces are used for descaling, metal cleaning, and pickling operations, but where the unit forms part of a production line continuous furnaces are generally preferred.

Tempering

With tempering and other lower temperature treatments for steel, precise control of atmosphere composition is not so important, since the rate of decarburization is so slow that it may be completely disregarded. Attention must be given to the possibility of sooting by thermal dissociation of carbon monoxide and to embrittlement produced by hydrogen absorption. To overcome these difficulties and yet still maintain conditions under which steel will be protected from oxidation, the atmosphere generally contains a high percentage of nitrogen. Forced circulation within the furnace chamber serves to maintain uniform conditions throughout the work. Other heat-treatment equipment also incorporates this feature.

Non-ferrous metallurgy

Controlled-atmosphere requirements in non-ferrous metallurgy are normally less stringent than those for iron and steel processing. Certain special applications call for precise control of water or some other constituent as, for example, the removal of sulphur compounds from gases used in bright annealing copper. A knowledge of the metal's physical properties is necessary when selecting a suitable atmosphere composition even though several constituents may be equally inert. For instance, most brasses lose zinc by volatilization above 430°C but it has been found that the rate of volatilization is to some extent dependent on the density of the surrounding atmosphere: hydrogen allows greater zinc losses than do more dense gases.

Brazing under controlled atmospheres has grown rapidly in importance in recent years and the joining of two parts may be effected by using special solders, copper and brasses. Reducing atmospheres are generally used especially with copper—the normal brazing material for mild steel —as it eliminates the necessity of a flux and protects the steel surface during processing. Atmospheres derived from ammonia or an exothermic gas produced from burnt town's gas are normally used, the latter requiring purification to remove all traces of hydrogen sulphide, which rapidly forms a black sulphide film on copper. Despite this, exothermic gas generally shows considerable economic advantages over the atmospheres produced from ammonia.

Combined processes for simultaneous brazing and hardening of stainless steels require special alloys to withstand the higher processing temperatures. Powdered metals are frequently sintered in an atmosphere of hydrogen or a mixture of hydrogen and nitrogen to ensure that they exist in a fully reduced state.

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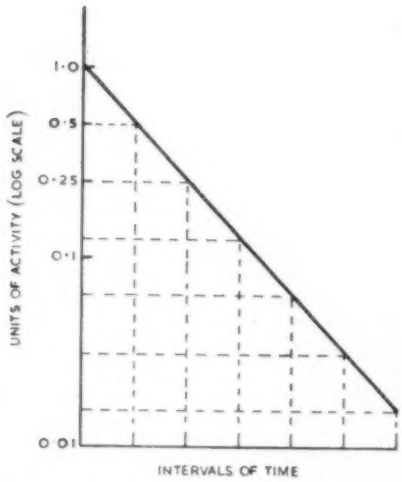


3 *Decay curve—semi-log plot illustrating 'half-life'*

substituting in (i):

$$\frac{N_0}{2} = N_0 e^{-\lambda t_{\frac{1}{2}}}$$

$$\text{or } t_{\frac{1}{2}} = \frac{0{\cdot}693}{\lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

Since the expression for half-life in equation (ii) does not contain N, the value of the half-life of a particular radioisotope is independent of the amount of material present. Half-lives vary considerably from fractions of a second to millions of years, it is thus a factor to be taken into consideration when deciding the feasibility of a particular isotope to an experiment.

Production of radioisotopes

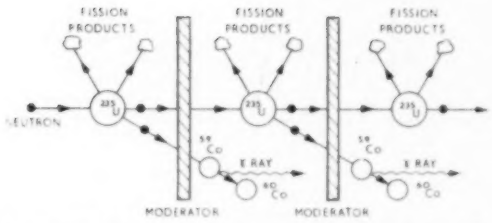
By far the greater proportion of radioisotopes are prepared by the irradiation of a stable isotope in the high neutron flux of a nuclear reactor or pile. If ordinary cobalt metal is so irradiated the Co-59 atoms capture a neutron and produce Co-60, gamma radiation being emitted in this n, γ reaction. The gamma radiation can be likened to the heat of reaction:

$$^{59}\text{Co} + {}^{1}n \rightarrow {}^{60}\text{Co} + \gamma$$

similarly with gold:

$$^{197}\text{Au} + {}^{1}n \rightarrow {}^{198}\text{Au} + \gamma$$

Both ^{60}Co and ^{198}Au are unstable and radioactive, ^{60}Co having a half-life of 5·3 years and ^{198}Au 2·65 days.



4 *Nuclear fission and neutron capture by ^{59}Co to give ^{60}Co*

The pile consists of an assembly of uranium rods sheathed in some suitable canning material like aluminium and arranged in a lattice pattern in a graphite moderator. Natural uranium is 99·3% ^{238}U and 0·7% ^{235}U. It is the ^{235}U nucleus which is the more readily 'fissile,' *i.e.*, on collision with a neutron the nucleus splits into two fragments (fig 4) and at the same time releases energy together with an average of 2½ neutrons per fission. A typical fission may be represented by the equation:

$$^{235}_{92}\text{U} + {}^{1}_{0}n \longrightarrow {}^{95}_{36}\text{Kr} + {}^{139}_{56}\text{Ba} + 2{}^{1}_{0}n + \sim 200 \text{ Mev.}$$

The yield of fission products is shown graphically in fig 5—the log of the fission yield is plotted against the mass number. Some useful radioisotopes are now being separated from the fission products; it can be seen from the graph that ^{90}Sr and ^{137}Cs are produced in relatively high proportions.

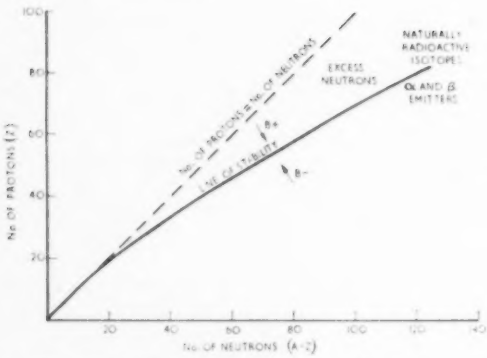
The neutrons which are released in fission are very energetic and have to be moderated or slowed down by a series of collisions with the carbon atoms of the graphite. The 'slow' or 'thermal' neutrons may then bring about further fissions so leading to a chain reaction, or be captured by other elements present in the pile.

It does not necessarily follow that a radioisotope will be produced by irradiating every element in the pile, it all depends on the capture cross section (σ). Stable isotopes with a low value of σ do not readily absorb neutrons, those with a high value readily do. This means of course that the materials out of which the pile is constructed must have low capture cross sections and so metals like zirconium, niobium and beryllium are playing an ever increasing part in nuclear engineering.

Unit of radioactivity

The unit of radioactivity is the Curie. It is the activity which was supposed to be associated with one gram of radium in the classical days of radioactivity:

1 Curie = $3{\cdot}7 \times 10^{10}$ disintegrations per second. This is too large for most radiochemical work and is



1 *Neutron-proton ratio and stability of isotopes*

or so natural elements. When the neutron-proton relationship is drawn for these stable nuclei a ' line of stability ' can be drawn running through the band containing the stable nuclides (fig 1). For the lighter isotopes the neutron-proton ratio is approximately 1 : 1; with the heavier isotopes it increases, indicating that an excess of neutrons is necessary to maintain stability. Neutron-proton ratio is an important factor, though not the only factor, which decides stability, but an excess of one or the other leads to unstability. The atoms then disintegrate and undergo a transformation by ejecting particles or radiation, as a means of achieving stability (Table III).

TABLE III *The isotopes of carbon*

Isotopic mass	No. of Protons	No. of Neutrons	Stability	Mode of decay	Half-life
10	6	4	Radioactive	${}^{10}_{6}C \rightarrow {}^{10}_{5}B + \beta^+$	19·0 sec
11	6	5	Radioactive	${}^{11}_{6}C \rightarrow {}^{11}_{5}B + \beta^+$	20·5min
12	6	6	Stable	None	—
13	6	7	Stable	None	—
14	6	8	Radioactive	${}^{14}_{6}C \rightarrow {}^{14}_{7}N + \beta^-$	5,600 y
15	6	9	Radioactive	${}^{15}_{6}C \rightarrow {}^{15}_{7}N + \beta^-$	2·3 sec

Where there is an excess of protons as in ^{10}C and ^{11}C, one proton apparently changes into a neutron with the ejection of a positive electron or positron. Where there is an excess of neutrons as in ^{14}C and ^{15}C, a neutron changes into a proton with the ejection of a negative electron or β^- particle.

Besides β radiation, unstable isotopes may emit either α or γ radiation. α radiation is the helium nucleus consisting of two protons and two neutrons. It is a radiation which is invariably associated only with the heavy elements; there are very few α emitters of the lighter elements. γ radiation is electromagnetic radiation produced within the nucleus and of shorter wavelength than x-rays, consequently it has a greater penetrating power.

Disintegrating rate and half-life

Radioisotopes are continually emitting some type of radiation and the assumption is made that all radioactive nuclei of a particular isotope have an equal probability of undergoing decay. It is an assumption which is borne out by experience and means that the number of atoms which decay in a given interval of time is proportional to the number of atoms present:

$$\frac{dN}{dt} = -\lambda N$$

where N = number of atoms present at time t, and λ = the decay constant for that particular isotope.

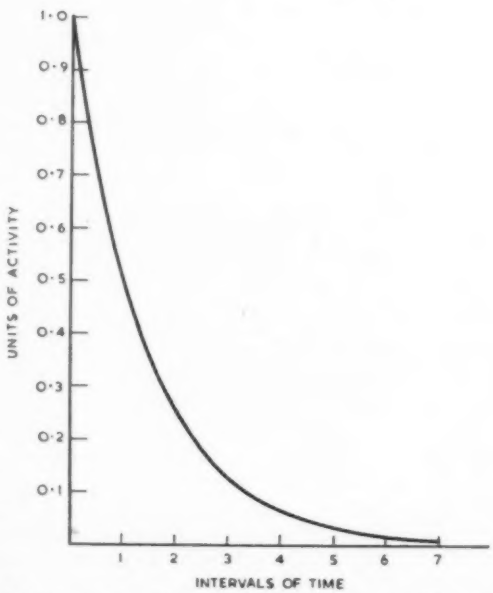
Integrating:

$$N = N_0 e^{-\lambda t} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

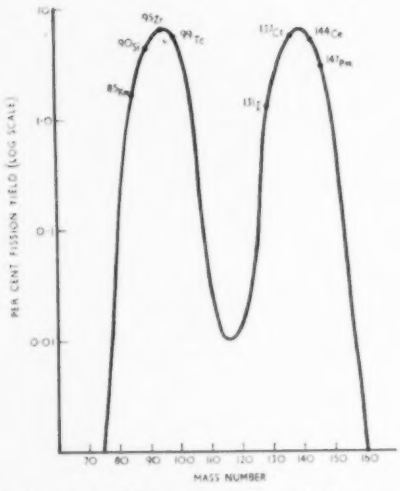
where N_0 = number of atoms present at zero time.

This is an equation to a typical exponential curve (fig 2), and therefore if the logarithm of the activity (a measurement of N) is plotted against time, the result is a straight line (fig 3). It is therefore difficult to speak of the full-life of a radioisotope; it is more convenient to speak of the ' half-life.' This is the time required for the activity to decrease by a factor of two.

Thus if $t_{\frac{1}{2}}$ be the half-life, then $N = \frac{N_0}{2}$, and by



2 *Decay curve—linear plot giving an exponential curve*



5 *Fission yield of ^{235}U and some of its useful fission products*

subdivided into the millicurie (mc or 10^{-3}c) and the microcurie (μc or 10^{-6}c).

The curie is the unit of disintegration rate and does not always equal the emission rate of beta particles or gamma photons, for in some disintegrations two or more particles may be emitted, *e.g.* Co-60 emits two characteristic gamma photons together with beta radiation.

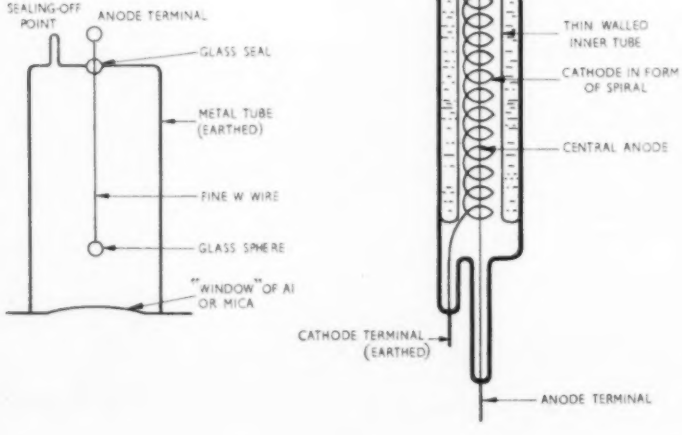
The activity of a radioactive element is dependent not only on the mass of the element present but also on its atomic mass and its half-life. Thus 1 curie represents 1 g of radium ($t_{\frac{1}{2}}$ = 1,580 years), but only $3{\cdot}18 \times 10^{-5}$ g of ^{32}P ($t_{\frac{1}{2}}$ = 14·3 days). As can be seen from these figures quite small amounts of the shorter lived isotopes represent very high disintegration rates.

Detection and measurement

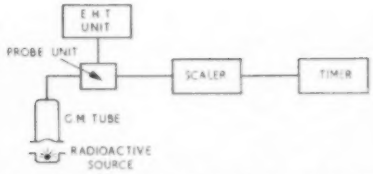
Historically the first means used for the detection of radioactivity was the photographic plate,[3] and this method still finds considerable applications, particularly in the field of gamma radiography.[4] Photographic plates and films have the advantages of cheapness, permanence of record and moderate quantitative accuracy. They are in many cases far superior to other methods when it is required to map out the location of activity in specific samples, as is done in the autoradiographic techniques.[5] By using these techniques much work has been done in wear and lubrication studies,[6] corrosion, the distribution of specific elements in alloys, diffusion and self-diffusion of metals,[7] segregation[8] and investigations on the solidification boundary in continuous casting.[9]

For more accurate quantitative determinations the Geiger-Müller counter and the scintillation counter are used. Briefly the Geiger-Müller counter (or G-M tube) is a simple device (fig 6) consisting essentially of two electrodes which provide a high electrostatic field in a suitable gas. As the radiation passes through the gas ionisation occurs and the ions move towards their respective electrodes. Thus a pulse is produced from a single atomic particle, which can be amplified and fed into a scaling unit or scaler (fig 7).

The modern scintillation counter is an electronic development of the somewhat laborious method



6 *The two common types of Geiger-Müller tubes (a) end window, (b) liquid type*



7 *Block diagram of equipment used in G-M counting*

used by the early workers in the field. If the radiation is allowed to fall on a suitable phosphor like NaI-Tl crystal or zinc sulphide, a scintillation is produced. If the phosphor is in direct contact with a photomultiplier with a light sensitive cathode, the light flash can be converted into an electric pulse which can be detected and counted (fig 8).

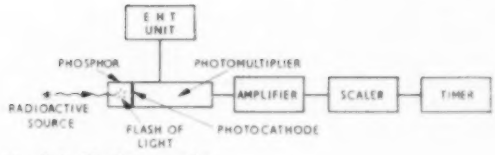
Absorption of β- and γ-rays

The use of β- and γ-rays in radiography for detecting flaws in metal castings and welds is a well established practice. The darkening of the film corresponds to the density variations in the test piece. The variation of the radiation intensity with absorber thicknesses has been found to be sufficiently sensitive enough for this property to be used in thickness gauges.[10] It is particularly useful for the continuous checking of the thickness of materials produced in continuous sheet form: paper, linoleum, strip metals, etc. In the transmission gauge the material passes between the source and the counter and a direct reading of the thickness is obtained without touching the material. In many cases, automatic control for adjusting the positions of the rollers is possible should the thickness of the material vary beyond pre-determined limits. Some of the more common radioisotopes used in transmission gauges for steel rolling are given in Table IV.

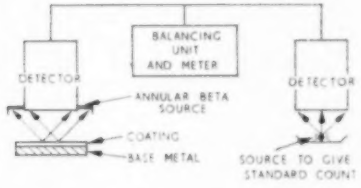
TABLE IV *Sources used in transmission thickness gauges*

Isotope ..	^{204}Tl	^{90}Sr	^{170}Tm	^{192}Ir	^{137}Cs	^{60}Co
Half-life ..	4·4 y	28 y	127 d	74 d	30 y	5·3y
Useful range	0·0005–	0·003–	0·01–	0·25–	0·25–	0·5–
for steel, in	0·007	0·035	0·30	1·50	1·50	3·0

Beta particle back-scatter gauges are used to measure the thicknesses of coatings such as paint or metal platings on a base metal. The arrangement is illustrated in fig 9. The proportion of beta particles scattered back into the detector depends not only on the thickness of the coating but also on the atomic number of the surface layer. The efficiency of the method is increased when there is a large difference between the atomic number of the coating and the base metal. Thicknesses down to 0·75 μ of tin or cadmium on iron have been measured to within 0·05 μ using ^{204}Tl as a source.



8 *Scintillation counting*



9 *Back-scattering of β particles to measure coating thickness*

Uses in steel production

Tracer techniques have been applied to many problems in the control and research of steel production. It is only possible to mention a few, but an excellent review is given by Samarin[11] of the uses of tracers in the Russian steel industry.

Voice[12] describes the use of radon to determine the gas transit time in a driving blast furnace, and the use of ^{60}Co indicators for the determination of blast furnace refactory wear. Small pellets of ^{60}Co were built at known depths into the brickwork and their gamma activity detected outside the furnace with a scintillation counter. When released due to wear, they could be detected in the iron output of the furnace.

Winkler and Chipman[13] were the first to use ^{32}P in studying the equilibrium of the reaction in dephosphoration. The distribution of quite a number of elements like phosphorus, sulphur, calcium and sodium between the iron and the slag, has been followed by using radioactive tracers of these elements. Similarly, the distribution of skin-forming elements on the surfaces of dissolving non-ferrous metals has been investigated by the use of such isotopes as ^{64}Cu, ^{65}Zn, ^{59}Fe, ^{203}Hg, ^{35}S, ^{126}Sb, ^{76}As, ^{110}Ag and ^{45}Ca.

Analytical methods

The use of radioisotopes as tracers is becoming more widely used in solving many theoretical and practical problems in analytical chemistry. An ever increasing number of such isotopes are being used to study the behaviour of small quantities of elements present in solutions, especially in the fields of chromatographic separations, coprecipitations, adsorption, and the electrochemical separations of metals. The presence and effects of trace quantities

of elements is so important in the study of pure metals, semi-conductors and alloy systems. Such methods have been used considerably in investigating the general chemistry and metallurgy of similar metals like zirconium and hafnium, and niobium and tantalum. In the case of the former, a small amount of hafnium in zirconium considerably affects its nuclear properties although the chemical properties of the two metals are very closely related. By using labelled hafnium or zirconium it is possible to follow the efficiency of a method of separation, and to quantitatively determine the amount of hafnium present by what is known as the isotopic dilution method.

Radioactivation analysis[14] is probably one of the most important advances in recent years for determining trace quantities of elements in metals and transistor materials. It is a very sensitive and specific method. It is based upon the irradiation of the sample under investigation in the neutron flux of the pile, so as to produce a radioisotope which can be separated and its activity measured. A measure of the activity is a measure of the content of the element. An example is provided by the determination of arsenic in germanium,[15] the method being sensitive to one part in 10^8. Another is the determination of phosphorus in pure iron.[16]

For differing elements the sensitivity of the method varies from 10^{-5} to 10^{-11} gram, but it is possible to determine over 40 elements at concentrations of the order of 10^{-6}% using a neutron flux of 10^{11}—10^{12} neutrons per sq cm/sec. Recent work has indicated that impurities in silicon can be determined to a sensitivity of 10^{-8} arsenic, 4×10^{-9} copper, 10^{-10} gold, etc. This is a very sensitive method for determining sub-microgram quantities.

The examples described above are just a few of the many ways in which radioisotopes are being used in metallurgy, both in control and research. They offer the industrialist and the research worker a potentially unlimited field for investigating many of the problems which have hitherto proved difficult or impossible by conventional means.

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Combined desulphurizing and sulphuric acid plant

New process developed by Appleby-Frodingham

AFTER TEN YEARS OF EXPERIMENTS and pilot plant trials, Appleby-Frodingham Steel Co, a branch of the United Steel Companies Ltd, has developed an entirely new combined desulphurizing and sulphuric acid plant which is claimed to incorporate major advances on any existing similar process. The first full-scale plant is now being installed at Appleby-Frodingham and is due for completion by mid-1959.

At most integrated steelworks, a certain proportion of coke-oven gas is used to fire the open-hearth melting furnaces, the remainder being used in reheating furnaces and soaking pits. This gas contains about 1% sulphur which, apart from adding to the difficulties of making low sulphur steel, results in considerable quantities of sulphur dioxide being released into the atmosphere. In an integrated works making a million tons of steel ingots a year the use of the Frodingham desulphurizing process enables the sulphur dioxide to be recovered, from which as much as 250 tons of sulphuric acid can be produced each week.

In the case of ordinary gasworks supplying town's gas, there is a statutory obligation to reduce the sulphur content of the gas to the equivalent of less than 2 parts/million by volume of sulphuretted hydrogen, a necessity which entails the provision of costly and extensive purification plant. Even after this is done, however, there remains a residue of organic sulphur which cannot be removed in existing purification equipment, and which causes corrosion in domestic hot water and similar appliances.

The plant developed by Appleby-Frodingham, which consists essentially of a fluidized hot iron oxide absorber and regenerator, is capable of removing both hydrogen sulphide and organic sulphur to very low levels; at the same time, too, it enables the recovery of considerable quantities of sulphuric acid. The heat requirements of the plant are met by the combustion of the absorbed sulphur and, once started up, it is self-sustaining for heat.

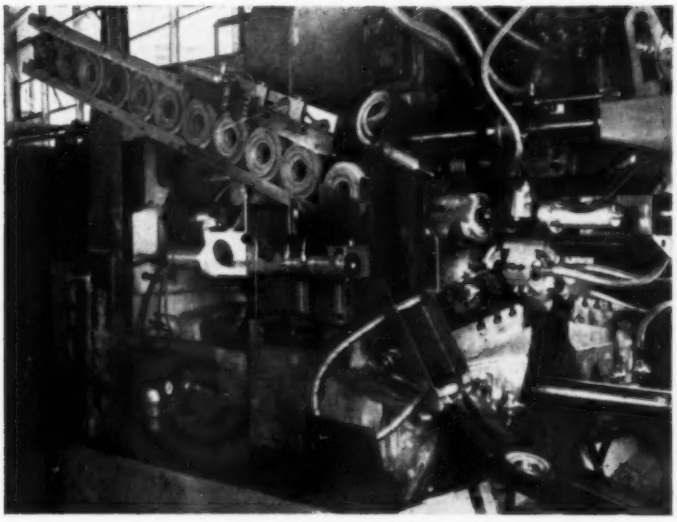
Pilot plant successful

A pilot plant has been in successful operation for two years, purifying up to 3 million cu ft of coke-oven gas per day. The full-scale plant, when completed, will deal with 32 million cu ft of gas per day.

Because the process employs hot gas, it is very much faster than conventional iron oxide boxes or purification towers, while the use of fluidized beds reduces the amount of spent oxide by four-fifths and simplifies its handling and distribution. In compactness and capital cost, the process compares very favourably with existing methods, while the entire operation of the full-scale plant is capable of being handled by two men per shift.

Under the provisions of the Clean Air Act, the height of chimneys discharging sulphur dioxide to astmosphere may be subject to regulation and this, combined with the economic and technical factors already mentioned, suggests that the new Frodingham desulphurization process is likely to be of particular interest to the steel industry, the gas industry—especially in the case of the larger gasworks—and the chemical and petroleum industries.

Appleby-Frodingham have appointed two licensees to build plants based on this process. They are Henry Balfour & Co Ltd and W. J. Fraser & Co Ltd. The unit at present under construction at the Appleby-Frodingham works is being built by W. J. Fraser.



Work handling for multi-spindle automatics

1 *Loading heavy castings*

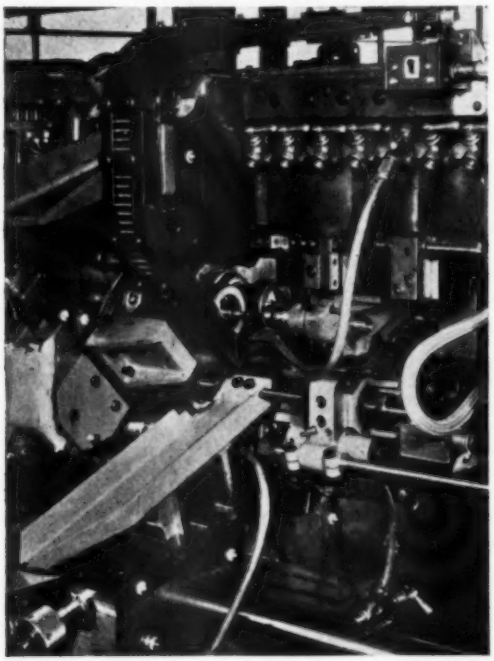
Multi-spindle automatic lathes represent one of the fastest forms of production. Bar machines are capable of cycle times as fast as two seconds for one, or sometimes two, pieces. Chucking automatics, however, have often been restricted, not only by the size and shape of the workpieces but also by the necessary delays involved in loading the machine and re-starting it by hand. This article describes some of the work-handling devices developed by Wickman Ltd, to eliminate these delays

THE FUNCTION of work-handling devices on multi-spindle automatic lathes is primarily to cut out the delays imposed by hand loading. Machines thus equipped have more flexibility and higher production potential, since they can either be incorporated into transfer line production systems or, when used as single units, group-fed by a single operator. Developments in machine-tool design and improvements in tooling are reducing cycle times to the point where hand loading is impossible to maintain. In these circumstances the use of work-handling devices not only speeds up production but also gives chucking machines the possibility of full machine utilization.

The following examples of work-handling devices may be broadly divided into two classes. The larger of these classes is that in which a fixed storage chute is used in conjunction with a swinging transfer arm. The components are stored in the chute, which has a trip mechanism to allow one component at a time to progress to the position of readiness at the end of the chute. From here the transfer arm picks up the component, swings to a position opposite the loading station and advances longitudinally to place the component in the open jaws of the chuck which is then closed automatically. The arm is then retracted but remains opposite the loading station. To unload the machined part, the arm advances again, picks up the component as the chuck opens and retracts further before swinging back to place the part in an ejection chute, often with the help of a stripper.

The attachment shown in fig 1 is part of a Wickman $7\frac{1}{4}$ in-6 chucking automatic and contains all the features mentioned above. The storage chute is in two parts, connected by a turntable, which is part of the arrangement for feeding the castings one at a time into the readiness position. From here the cam-actuated transfer arm picks up the component, gripping it internally by means of an air-operated expanding collet. The arm then retracts further, till it is in line with the ejection chute and swings back to place the finished component in this chute. In this case a stripper is provided to assist in the removal of the component and to guide it into the chute proper.

speeds up production and eliminates operator fatigue and delays which would occur with hand loading. The storage chute consists of a fixed and a moving part, the latter attached to the cross-slide and moving with it to bring the bottom component into the readiness position. A plunger, driven by a standard independent reaming attachment, then pushes it into the chuck. Ejection is carried out through the machine's bar feed mechanism acting on another plunger inside each chuck. The simplicity of the arrangement, together with the fast cycle time of 11·2 secs, allows a very high rate of production to be maintained. Where the cycle time is as short as this, it is important to have a storage chute of as large a capacity as possible, in order to avoid having to reload at too frequent intervals. Here the length of the chute has been gained and space saved by extending it over the top of the machine so that loading is done from the back of the machine. This chute holds about 80—100 workpieces, giving about 15—18 mins between refills of the chute.



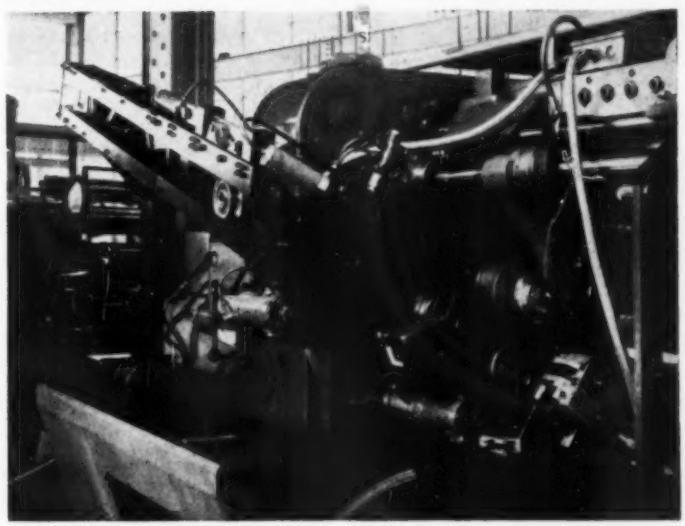
3 ABOVE *Chute and plunger loading device for cast-iron steel*

A similar arrangement has been devised to handle gudgeon-pin blanks, although in this case the whole of the storage chute is attached as one unit to the cross-slide. The loading plunger is again driven by what is basically the independent reaming attachment in station 5.

Another method of storing the work, the component again being a gudgeon pin, employs a hopper to store the components, with only a short loading chute. This gives a large storage capacity without extending the loading chute and enables the whole unit to be attached to the cross-slide. No trigger mechanism is necessary for this component, so that the whole arrangement is one of the simplest possible.

As an example of a highly complex loading and unloading attachment, with auxiliary equipment which makes it a true work-handling device, the

continued on page 238



4 *Loading, reversing and unloading attachment with two transfer arms*

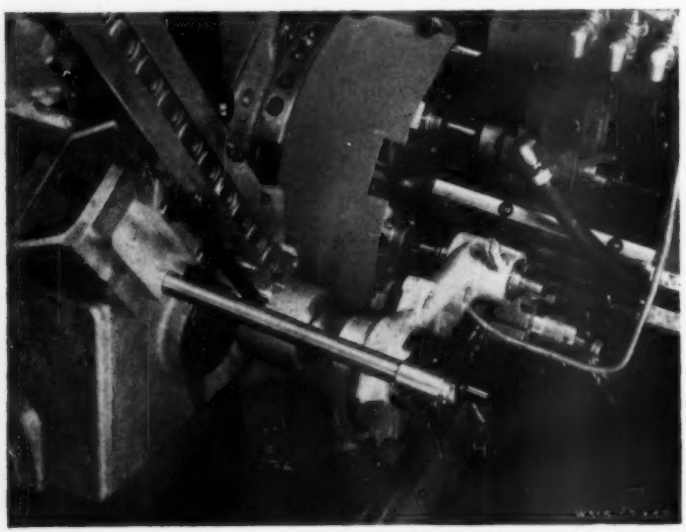
The size and weight of the component require that many of the auxiliary operations be performed by compressed air, the valves which actuate the movements being operated by cams. The trip and turntable mechanisms and the expanding collet are all operated in this way which has been found to be a highly reliable method of handling large parts.

Another similar device, in this case handling a very much lighter component, was fitted to a 6-in chucking automatic. The component is smaller than the one in the last example and an external chuck with three spring-loaded fingers is used on the transfer arm, while the machine chucks are of the three-jaw internal expanding type. The same procedure applies in this example, the arm picking up a component from the end of the loading chute and placing it in the chuck at the loading station and removing it from the same station after machining to place it in the ejection chute with the aid of a stripper. The action of this device is entirely mechanical, with a few electrical limit switches fitted as safety devices. The workpiece in this case is a light aluminium casting and the loading chute is therefore so designed that the piece is never allowed to fall any distance which might crack or distort it.

Another example of this type of loading attachment is shown in fig 2. Here the operation of the internal collet on the transfer arm is such that no stripper is required. The collet is a push fit in the bore of the gear blank to be machined and picks up the component, loads it and retracts in the usual way. When unloading, it picks up the finished part, retracts and swings over to a position above the ejection chute. As the arm finally reaches this position, a plunger on the back of the arm impinges against a special stop. This forces a sleeve over the collet, thus pushing the component off the collet. At all other times the collet is uncovered ready for handling the component. The component itself is such that no trip mechanism is necessary in the chute, one component falling into the readiness position as soon as the arm removes the previous one.

This type of attachment is generally more suitable for handling heavy or bulky components; for lighter or smaller parts and especially cylindrical parts, the type illustrated by the following three examples is usually more suitable. This differs from the first mainly in the fact that the storage chute moves, usually making use of the cross-slide movement, to bring the component in the readiness position exactly opposite the chuck in the loading station. Loading is then carried out by the action of a plunger, usually driven by a standard independent attachment similar to that used for reaming, which pushes the component into the chuck. The component is usually ejected by a spring-loaded plunger in the centre of the chuck. This system is often used on bar machines which have been converted to chucking operation, since the existing bar feed mechanism can then be used to actuate the ejection plunger.

The Wickman 1-in-6 machine shown in fig 3 shows not only how a bar automatic can be successfully modified to chuck operation to deal with small individual workpieces (in this case ground cast iron stick) but also how automatic loading



2 *Simple mechanized transfer loading attachment for loading gear blanks*

extent as does a protective layer to which a varnish has been added. The latest protection processes therefore aim at porous layers to which the varnish can easily adhere and which are sufficiently flexible to withstand certain changes of shape (deformations).

The 'Alodine' process produces such layers and is at present regarded as very promising. The solutions used for the aluminium parts contain in the main CrO_3, H_3PO_4 and fluoride. (Time of treatment about 3 min at a temperature of 40 to 55°C). The layer, which is greenish to grey, consists of Cr-Al phosphates with 18—20% Cr, 4-5 Al, 15—17 P and about 0·2% F. In view of its micro-porosity it forms an excellent base for varnishes and consequently considerably improves the corrosive resistance of the aluminium in combination with a layer of varnish.

Larger quantities can be treated with a spray; since only a degreasing and perhaps an after-passivation are required, five spray chambers are sufficient for a full treatment.

A similar process to that of Alodine is described under the name of 'Iridite'.[5] According to the manufacturer the iridite layer considerably improves the resistance to corrosion of the aluminium and forms a good base for varnishes. The layer is resistant to mechanical influences, not very porous, but not quite as hard and resistant to abrasion as aluminium oxide layers. Time of treatment is between 10 secs and 5 min. The layers can be produced by submerging, by spraying or by painting.

An entirely different working process was developed in Switzerland under the name of 'Alprox'.[6] Taking into account that the natural layer of oxide on aluminium is smooth and free from pores, and therefore presents a poor base for a varnish, this layer is by treatment with an alkalide oxidation solution converted into a cover which is then reduced in an acid bath until only an oxide skeleton remains. The numerous pores of this layer, which cover the aluminium surface like a fine mesh, are an excellent adhesion base for varnishes, and thus provide a good protection against corrosion.

Chemical surface protection methods also include wash primers.[7] These consist of chromate pigments, such as zinc tetraoxichromate, polyvinybutyrale as binding agents, phosphoric acid and alcohols, further small quantities of talcum and soot, and they are usually applied in a two pot process: 1, Binding agent + pigment and additions; 2, phosphoric acid in alcohols. Wash primers have given good results with aluminium alloys. They can replace the chemical protection methods in cases where the danger of corrosion is not very great.

Magnesium

Magnesium and its alloys require surface treatment even more than aluminium, as magnesium is still less noble, and is badly affected by all corroding materials.* Apart from MgO, magnesium fluoride and magnesium selenide are also used for protective covers. Most chemical protection processes are applied in combination with varnishes or paint covers, since the layers themselves are relatively porous and by themselves would hardly offer sufficient protection to the unnoble metal. The durability of the protective layer and its effectiveness therefore depend to a large extent on the quality of the varnish and the method of varnishing. According to their chemical composition the protective layers on magnesium can in the main be divided as follows:

(1) *Oxide layers* which consist entirely or mainly of MgO;

(2) *Fluoride layers* with MgF_2 as the principal component part;

(3) Other protective layers, for example, selenium or magnesium selenide.

Chromium acid salts play an equally important part in the oxidation process of magnesium as in that of aluminium. The best known methods are those of the I G Bitterfeld, known under the name of B S, B A, and B M processes. (B S—bichromate nitric acid, B A—bichromate alum, B M—bichromate magnesium sulphate).[8] The most widely used is the B S process.

The solution consists of 15% potassium or sodium dichromate and 20% concentrated nitric acid; time of treatment is between 15 sec and 3 min. The protective cover, with the colour of brass, apparently consists of magnesium oxide with a small content of magnesium chromate. According to W. O. Kroenig/G. A. Kostylew[9] the treatment with a nitric acid-dichromate solution is, compared with other chemical protective methods, most effective for magnesium alloys; the best protection is offered by a solution consisting of 40 g calium chromate and 180 g nitric acid (in a litre of water) heated to 80°C. The process is cheap and simple; it is adequate, without any after-treatment, in cases where the danger of corrosion is not great and in combination with a varnish it gives the metal quite a

*The particularly strong susceptibility of magnesium and its alloys is based on the fact that the MgO cover on the Mg has a smaller molecular volume than the metallic Mg. If M and D are the molecular volume and the density of the oxide, and m and d the corresponding seizes of the metal, then for magnesium we have

$\frac{M \cdot d}{D \cdot m} = 0{\cdot}84$, *i.e.* during the formation of the oxide there is a shrinking of the volume of the magnesium, and this results in pores and fissures in the oxide layer of this metal; the layer consequently does not offer protection.

Chemical surface protection of light metals

The following brief description of methods of protecting aluminium and magnesium from corrosion is translated from the German of Dr Eng A. Pollack, Leverkusen, Metall, September, 1957

ALUMINIUM ALLOYS which, if not protected, are susceptible to corrosion in an industrial atmosphere, in sea air, sea water, and salt solutions, must be protected from corrosion by means of suitable processes. (The natural oxide skin only partially protects aluminium, which is particularly sensitive to chloride.) This is even more important in the case of magnesium alloys, since magnesium is a less noble metal. Moreover, the layer of magnesium oxide which is formed naturally is very pervious, since the molecule volume of the MgO is smaller than that of the Mg. Numerous chemical and electrochemical protection processes have been suggested for both metals and their alloys. In spite of the certain advantages of the electro-chemically obtained layers, especially in the case of aluminium, there is an increasing preference for chemical processes, as they are simpler and more economical, and since their protective properties, when combined with varnishes, closely resemble those of the electro-chemical processes.

The most important of these processes produce layers which are particularly suitable as bases for varnish.[1] Many patents, and numerous publications in the technical press over the past few years have shown that in spite of good results obtained by some of these processes, the development in this field has not yet been completed.

Aluminium

Among the older processes which first seemed promising, but then receded into the background, until they are now of merely historical interest, one may mention those by Jirotka, Pacz and McCulloch.[2] The Jirotka baths, consisting of acids, alkaloids or neutrals, whose composition varied greatly, were supposed to provide the aluminium alloys with a layer of Al_2O_3 with the inclusion of more noble metals, such as Mn, Cr, Fe, Ni, Co, W, Mo, etc ; in the course of time these metals were themselves to be converted into oxides. But owing to the use of precious metals, the layers could not serve as protection for the less precious aluminium, therefore this process found hardly any application in practice.

Pacz proposed to treat the aluminium parts with hot solutions of Na_2SiF_6, Na_2TiF_6, or of sodium-oxalate with the addition of Ni, Co, or Mo compounds, and alkali-nitrates. The surface was supposed to become irridescent or to become covered with dark, heat-resisting 'stains' resistant to mechanical influences; above all it was to have an attractive appearance. Here too, there was hardly any question of protection so that this process did not become popular either.

McCulloch managed to obtain a white to greenish protective layer by submerging the parts into milk of lime to which he added $CaSO_4$. But this process was not put into practice either.

On the other hand the 'Protal' process, developed at about the same time by the Société Continentale Parker, is used, especially in France (for the manufacture of metal furniture, typewriters, refrigerators, bicycles, radio apparatus, motor vehicles parts, etc[3]). This process treats the aluminium parts in solutions that, apart from 1% alkaline, contain mainly 0·5% alkali vanadate, molybdate, wolframate, titanate, niobate, uranate, or manganate, with an addition of phosphate or organic acids; the complex salts of these metals (including chromium) can also be used. The well degreased aluminium parts must be treated in the Protal solution for some minutes at a temperature of 20 to 35°C. The protective layers, resistant to chemicals, which should consist of Al_2O_3 and the oxides of the added metals, and partly also of phosphates, are said to adhere well and to provide a good base for varnishes.

Among the older suggestions the MBV process and the allied EW process are the best known.[4] In the MBV process the work pieces (consisting of Al alloys free from Al and Cu) are submerged for between 10 to 30 min into a solution of 5% Na_2CO_3 and 1·5% Na_2CrO_4 heated to a temperature of 90—100°C. The dark grey layer probably consists of Al_2O_3 and Cr_2O_3. It adheres well, but is not resistant to abrasion; owing to its porosity it serves as a good base for paints and varnishes. Its protective properties can be improved by impregnation with water glass. In the EW process this is done by the addition of 0·1 g/l of waterglass to the MBV solution. The EW layer is practically colourless and transparent, much more resistant to abrasion, but owing to its density not suitable as a base for varnishes. The EW treatment increases the resistance to corrosion of the aluminium which is exposed to the influence of salt solutions, industrial atmosphere, etc., but it does not do so to the same

Series on heat treatment

The heat treatment of En steels

F. C. BIRD, A I M, and G. R. MORTON, F I M, A M I M M, M I B F

The heat treatment of typical examples of En steels is considered in relation to the transformation diagrams and hardenability curves. This is the sixth of the heat treatment of steel lectures given at the Wolverhampton and Staffordshire College of Technology to be published in this journal. Mr Morton is senior lecturer in metallurgy at the College, and Mr Bird is with Walter Somers Ltd

IN THE IMMEDIATE PRE-WAR DAYS very many varieties of steel were used and it became evident that some kind of uniformity was desirable. Attempts were made to restrict the number, and in the middle of the war era the first standard list B S S 970 was published. The original issue has been revised from time to time and certain additions made—the last being in 1955. Thus the En steels are a range standardized during a national emergency and because of proven utility, continued, enlarged and modified during the post-war expansion of metallurgical activities. A complementary publication, B S S 971, offers useful advice and classification to assist in the selection of an appropriate type, according to the physical properties desired and the size of section involved.

This article refers to their heat-treatment and in order to cover, in a representative form, the many steels referred to in the B S S, typical popular examples have been chosen. In each case the transformation diagram and hardenability curves are reproduced. The heat treatments discussed are based on the diagrams, and the practical aspects dealt with. In considering the applications of the transformation diagrams the limitations discussed in the first article should be borne in mind, and also the width of the composition range of each alloy series within the En specification.

En 3

C 0·25 max, Si 0·05—0·35, Mn 1·0 max, S 0·06 max, P 0·06 max.

A T T T diagram for a steel within this range is reproduced in fig 1 from which it will be seen that the curves for the beginning of the transformation intersect the temperature axis. Since for efficient hardening it is essential that the critical cooling rate is exceeded it is obvious from the diagram that steels of this type are non-hardening.

Superimposed on the T T T curve is a typical C C T diagram for a steel of somewhat similar analysis, and it will be seen that the diagram for continuous cooling has been moved downwards and to the right. Thus, in order to exceed the critical cooling rate, it is necessary to pass the temperature of the nose of the transformation curve in less than 1 sec, which confirms the non-hardening character of the steel. Such treatments as annealing and normalizing can, however, be applied.

En 9

C 0·5—0·6, Si 0·05—0·35, Mn 0·5—0·8, S 0·06 max, P 0·06 max.

The T T T diagrams for two alloys approximating to this specification are superimposed on fig 2. The curve A (C 0·54, Si 0·2, Mn 0·46) is within the specification, while B (C 0·50, Si 0·13, Mn 0·91) falls outside for manganese only, nevertheless the combination shows the effect of increasing the manganese content by displacing the transformation curves to the right. This serves to show the difference between alloys at the lower and higher end of the specification respectively, *i e* steels of the latter group are more easily hardened than those of the former.

In practice this steel is effectively hardened and provided that due consideration is given to ruling sections, cheapness combined with relative hardness are obtained.

B S S 970 lays down the maximum ruling section or thickness in which certain mechanical properties can be obtained by heat treatment from a specific steel. If, for reasons of cheapness, it is desired to

good protection. Methods of treatment with hot concentrated soda solution, partly under pressure, in order to obtain protective layers, are described by M. Straschill.[10]

Other manufacturers use the stability of the magnesium fluoride for the surface protection of magnesium. The layers obtained by submerging the parts in solutions of fluoride or hydrofluoric acid are thin, but they can be painted or varnished.[11] Straschill[12] points out that oxide layers obtained by treatment with soda solution under pressure can be converted into fluoride solutions after boiling them for 1½ hours; the covers then offer a good protection against corrosion and a good base for varnishes.

Of all the processes that use differently composed protective covers, the treatment with selenium compounds is the best known. The magnesium parts are submerged into a 10% solution of the selenium acid containing 0·5% of cooking salt.[13] Time of treatment at room temperature is about 5 min. The thin cover is said to consist of magnesium selenide and to be self-healing.

The process, which is considered as particularly advantageous, can be imagined as follows: If water penetrates into the pores of the layer and decomposes it, the selenium peroxide which thereby forms oxidises into selenium owing to the oxygen which in water is in a constantly dissolved state; the selenium closes the pores and 'heals' the cover. The 'healing' process continues so long as the water has access to the metal. Stability is finally achieved when all the pores have been closed by the selenium and the layer, which now consists of a mixture of magnesium selenide and selenium, has become a protective cover.

The processes for the chemical protection of the surface of magnesium have exceeded in importance those of the electro-chemical processes, because the advantages of the latter, when applied to this metal, in most cases do not warrant the higher costs involved.

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(1) B. F. H. Scheifele, *Werkstoffe und Korrosion*, 1954, **5**, 3, 94; A. Pollack, *Metall*, 1956, **10**, Nr 11/12, 523.
(2) For details see 'Gmelin's Handbook of Inorganic Chemistry', 8th edition, Syst Nr 33 (Aluminium), part A, (Lieferung) 3, 1936, Verlag Chemie, Berlin, p 466.
(3) *Beiztechnik*, 1954, **3**, No 9, 132.
(4) B. F. H. Scheifele, l c.
(5) R. Stricklen, *Materials and Methods*, 1952, **35**, No 2, 91.
(6) M. Schenk, *Metall*, 1952, **6**, No 5/6, 136.
(7) B. Elfisch, *Werkstoffe und Korrosion*, 1954, **5**, 54.
(8) For a detailed description of the bichromate processes, including those applied abroad (A M C and Dow processes), see M. Straschill, *Beiztechnik*, 1954, **3**, 3.
(9) *Korrosion und Metallschutz*, 1932, **8**, 147.
(10) l c, 5.
(11) F. Lohmann, *Oberflaechentechnik*, 1937, **14**, 134.
(12) l c, 22.
(13) From F. Lohmann, *Oberflaechentechnik*, 1937, **14**, 135, contains further source references; see also M. Straschill, l c, 22.

Work handling

concluded from page 235

arrangement shown in fig 4 is worthy of attention. The problem was that of machining both sides of a relatively heavy cast-iron workpiece in one machine cycle. The machine is a Wickman 6⅝ in-6 chucking automatic, modified to double indexing, which means that each spindle indexes two stations at a time, thus giving two separate machining sequences, each using two tooling stations. The remaining two stations were used for loading and unloading and to avoid delays in the sequence the component had to be reversed automatically before it passed from the first machining to the second.

The sequence of operations was as follows. From the initial loading chute, very similar to that shown in fig 1, the part was loaded by a swinging transfer arm into the chuck at station 5, and was then machined on one side in stations 1 and 3 before being unloaded from station 5 by the same arm, which then placed it in a special 180° turntable. This reversed the part and fed it into a secondary loading arm, which loaded it into the chuck at station 6. The other side of the part was then machined in stations 2 and 4 and it was removed from station 6 by the secondary arm, the movement of which was longitudinal and placed in an ejection chute. The effect of careful arrangement of the tooling, which allowed 19 operations to be carried out in four stations, in enabling the two loading stations to be kept clear, should not be overlooked, as this contributed materially to the successful operation of the layout. The cycle time for the whole operation, *i e* machining both sides, was 30 secs, in which time all the loading and unloading operations are included.

Arrangements of the kind described in this article retain a high degree of flexibility as well as giving a greater capacity for fast production. They represent a process of development, as yet far from complete, towards fully automatic production.

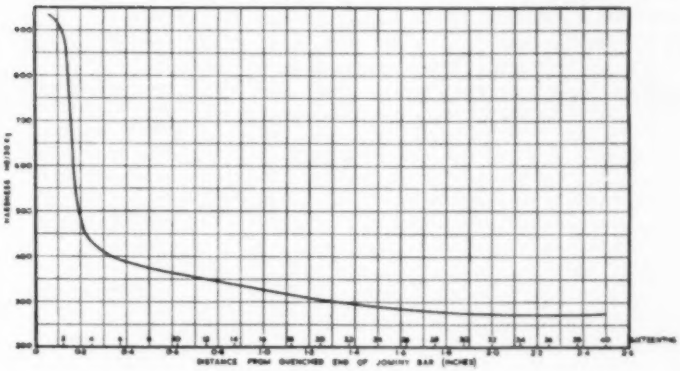
Television for atomic power station

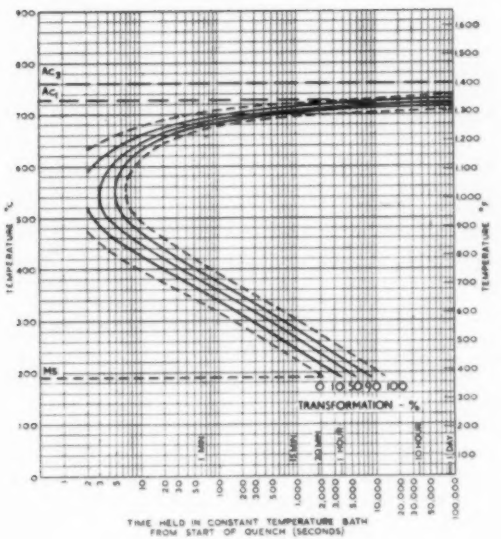
The first order for a television nuclear reactor camera has been placed with Pye Ltd. It will be used at the Central Electricity Generating Board's Bradwell atomic power station. The camera will help engineers to inspect the interior of the station's two reactors when they come into operation during 1960.

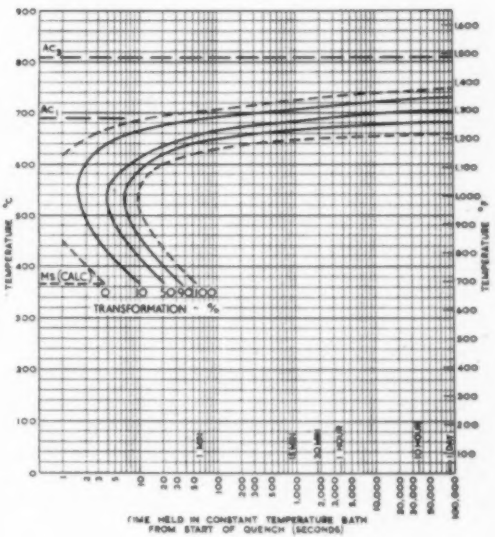
The first of three Pye TV cameras for exclusive use in the atomic energy industry was put into operation at Calder Hall in 1956. It was 3 in dia and 40 in long and had its own source of illumination. A special cooling system was also provided. The second camera led to the development of a camera which incorporates facilities for handling objects within the reactor core. It is a camera similar to the latter, which is to be delivered to the Central Electricity Board sometime next year.

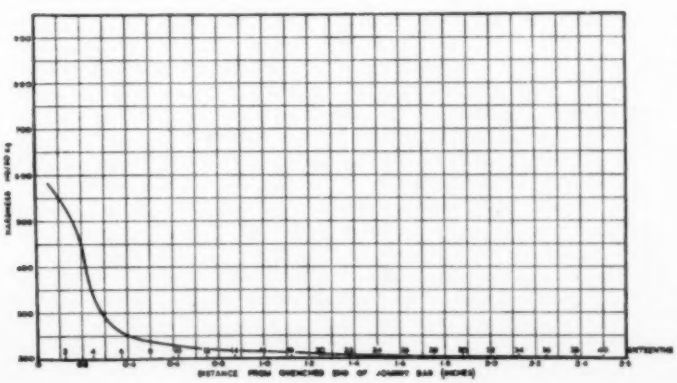
4 (BELOW), **5** (RIGHT)
En **44**—*carbon spring steel for oil-hardening and tempering (higher carbon content)*

Austenitizing conditions: 780°C (1,436°F); 30 *min*







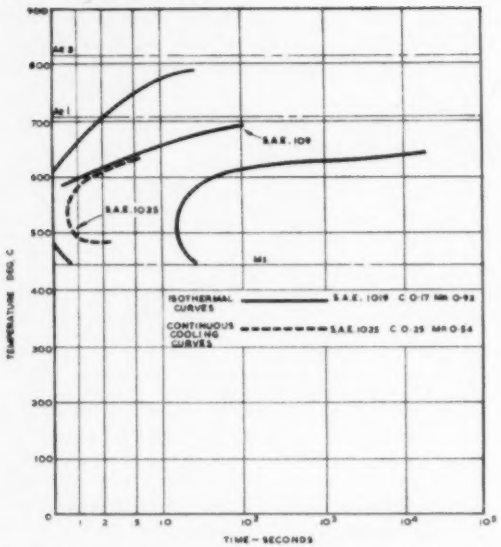


6 (ABOVE), **7** (LEFT)
En 12—1% *Ni steel*

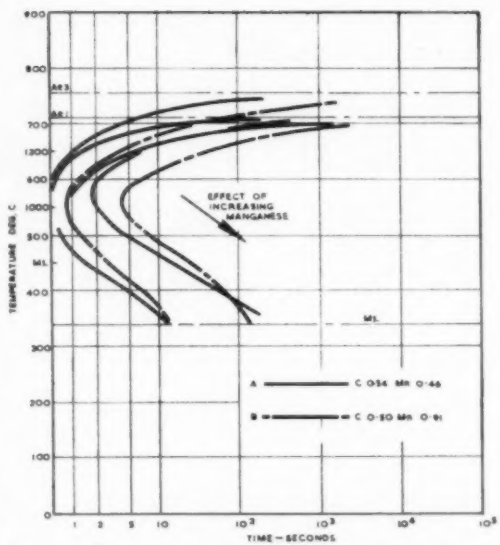
Austenitizing conditions: 845°C (1,553°F); 30 *min*

Atlas of Isothermal Transformation Diagrams of BS - En steels

I S I Special Report No 56



1 *T T T and C C T curves for steels approximating to En 3*



2 *T T T curves for En 9 steel with those of high manganese alloy superimposed*

purchase low-alloy material, one must be prepared for the fact that its properties may only be obtained on a small section. If, however, the same properties are required on larger sizes it will be necessary to obtain a higher alloyed and higher priced steel. In consequence, as the property requirements increase in tensile strength and hardness or the section in size and thickness, so does the type of steel increase in alloy content.

Despite, however, the short time lapse as shown by the T T T curves this steel is hardened and tempered, and since the structure will not contain more than about 10% of martensite the steel is of the shallow hardening type. This is shown in the end quench curves (fig 3).

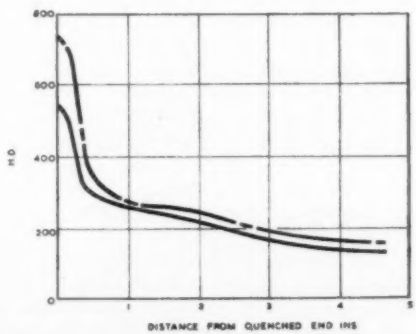
En 44

C 0·9—1·2, Si 0·3 max, Mn 0·45—0·7, S 0·05 max, P 0·05 max.

This diagram (fig 4) reflects one of higher carbon content with very little, if any, alloying elements added.

The nose of the curve is sufficiently far to the right to enable the critical cooling rate for thin sections to be exceeded by either oil or water quenching, and the conventional hardening and tempering operations, along with those of martempering and austempering, are all possible. Softening operations and normalizing are also readily applied. Thus it is possible to obtain, by the various treatments, all the micro-constituents found in steel. Bainite, however, whilst produced by austempering, is not found on continuous cooling where the products may be combinations of pearlite, 'troostite' ($\alpha Fe + Fe_3C$) and martensite. From the hardenability curve (fig 5) it is seen that a surface hardness of approximately 900 V D H may be obtained and that this falls off rapidly as the distance from the surface increases, *i e* it has high hardness but low hardenability.

En 44 is essentially a spring steel and may be obtained in the fully-annealed or cold-rolled condition. It is extensively used for laminated leaf springs and can be jig-quenched into water to give intense hardness, retaining a considerable degree after tempering, together with great flexibility.



3 *Hardness values for En 9 steel*

En 12 1% Ni steel

C 0·3—0·45, Si 0·1—0·35, Mn 1·5 max, Ni 0·6—1·0, S and P 0·05 max.

The curve for the beginning of the austenite to pearlite transformation is within the vicinity of the vertical temperature axis (fig 6) which suggests that steels of this specification are of low hardenability. This fact, and also the low hardness value, are seen in the hardenability curve (fig 7), which shows a maximum hardness value of approximately 600 at the surface falling to 200 at 0·4 in. below the surface.

In order to obtain maximum hardness it is necessary to cool extremely rapidly. Annealing by continuous cooling is, however, relatively easy.

The effect of the alloy addition of 1% nickel enhances the ability to obtain a higher ultimate stress in a larger ruling section. This steel can be heat-treated to a tensile strength of 40—50 tons sq in. up to 6 in. diam. This is because the nose of the T T T curves, though still towards the left of the diagram, shows a broader band between the initiation and completion of transformation, than would a plain carbon steel. Nickel being a solute element, strengthens the ferrite, thus the imperfect quenching of a larger section, passing through the outer nose of the curve, would still leave, after the tempering operation, a satisfactory combination of physical properties at moderate tensile strength.

En 16 Mn-Mo steel

C 0·25—0·4, Si 0·1—0·35, Mn 1·3—1·8, Mo 0·2—0·35.

In this case the curves have now moved considerably to the right and it will be noted that a shelf which signifies the bainite transformation portion becomes manifest. This means that on continuous cooling at progressively slower rates the structures obtained include: Martensite; bainite and martensite; bainite; ferrite, pearlite and bainite; and ferrite and pearlite; *i e* bainite becomes a product of continuous cooling. It will also be seen that isothermal annealing is impracticable except within the temperature range 580—630°C when fine pearlite with its lack of complete softness results. Continuous cooling annealing is usual, though the time required to pass through the transformation in order to obtain complete softening may be in excess of 10 h. The martempering process is possible for very small sections and austempering for somewhat larger sizes.

The hardenability curve (fig 9) confirms the effect of the displacement of the transformation curves to the right on hardenability, and the steel has a maximum hardness of over 600 V D H with a fair response to depth of hardening.

En 17 Mn-Mo steel (higher molybdenum)

C 0·3—0·4, Si 0·1—0·35, Mn 1·3—1·8, Mo 0·35—0·55.

This specification varies from that of En 16 only in minimum and maximum molybdenum content, the maximum of the En 16 specification being the minimum of the En 17. The effect of this on the T T T diagram (fig 10), is that the curves are moved considerably to the right and a well-defined bainite shelf makes its appearance.

This means greater hardenability and greater hardness as shown in fig 11, the maximum figure obtained on quenching from the austenitizing temperature being in the region of 700 V D H, an increase of 100 V D H as compared with En 16.

Since the bainite shelf is more pronounced the production of bainite on continuous cooling at speeds exceeding the critical cooling rate for pearlite is enhanced, in fact, small sections when air cooled will contain relatively large proportions of this constituent. Annealing from temperatures above the Ac_1 becomes more difficult, and isothermal annealing is limited to a narrow temperature band around 630°C. The increase in molybdenum facilitates austempering and martempering in small sections and the normal hardening and tempering operations are especially easy if bainite hardening is acceptable for larger sections. It should be noted that for martempering operations, up to approximately 20 sec in the quenching bath can be allowed for temperature equalization before removal, to allow the low temperature martensite transformation to take place.

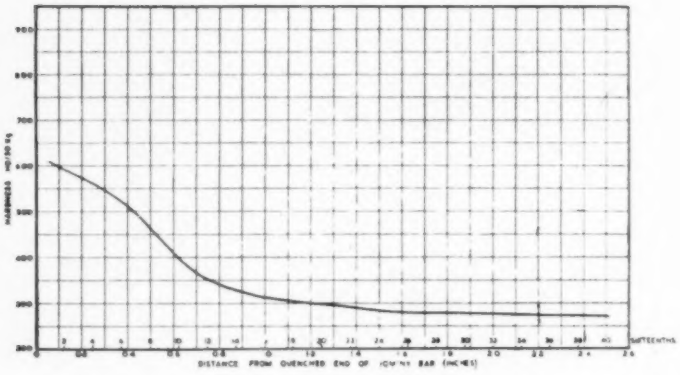
These latter two steels serve a useful purpose where moderate strength only is required and nickel-containing alloys are either too expensive or were until recently in short supply. The ruling section is of considerable importance in the absence of this ferrite-strengthening element. It is desirable to avoid quenching through the pearlite nose so that En 17 is preferred for larger sections. The flat bainitic shelf offers considerable latitude in cooling.

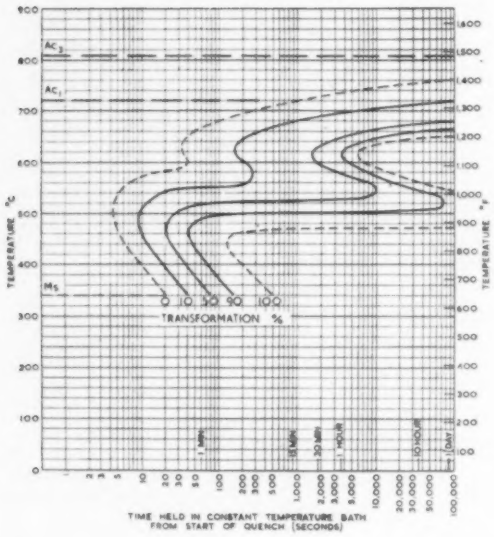
Even greater hardness may be conferred by raising the average carbon content approximately to 0·4% with perhaps 1% of chromium as in En 18, but the hardenability, *i e* the depth of hardness penetration, is limited, and even the addition of 0·3% of molybdenum to the chromium (En 19), though it improves this aspect, scarcely matches the results conferred by the higher molybdenum and manganese found in En 17, where larger ruling sections are involved.

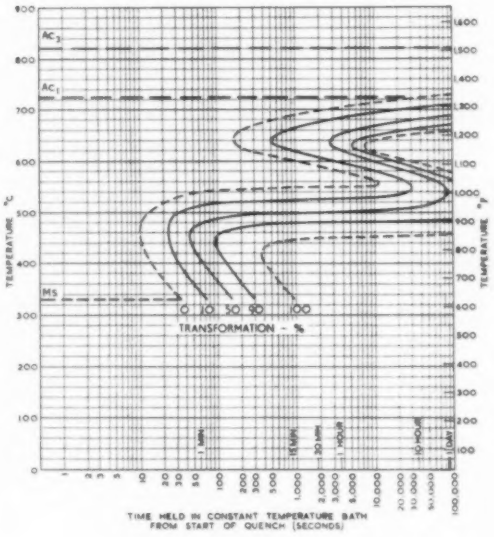
These four steels, En 16—19, overlap in hardness ranges so that the issues of surface hardness and wear provided by chromium, and hardenability given by increased amounts of manganese and molybdenum, must be assessed according to the

8 (BELOW), **9** (RIGHT)
En 16—*Mn-Mo steel*

Austenitizing conditions: 845°C (1,553°F); 30 *min*

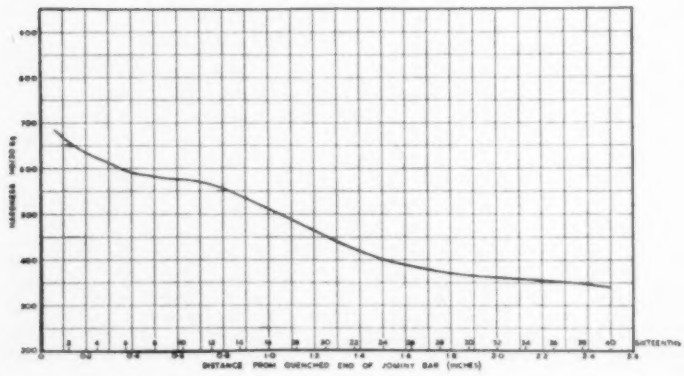






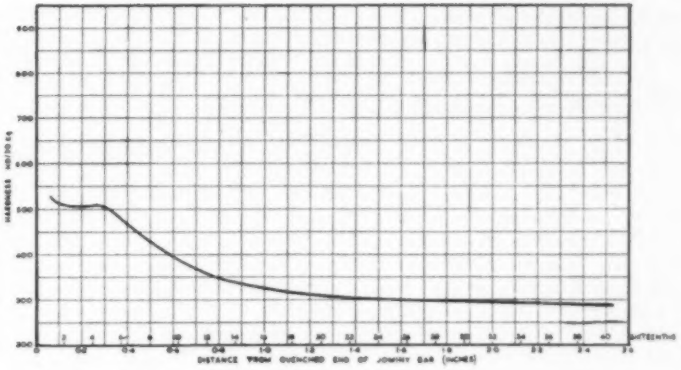
10 (ABOVE), **11** (LEFT)
En 17—*Mn-Mo steel (higher Mo)*

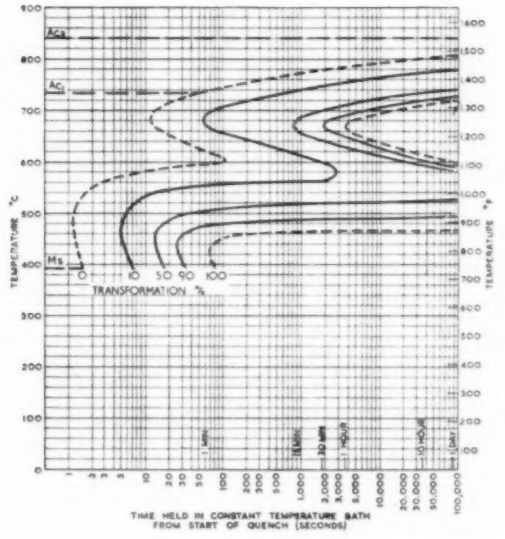
Austenitizing conditions: 845°C (1,553°F); 30 *min*

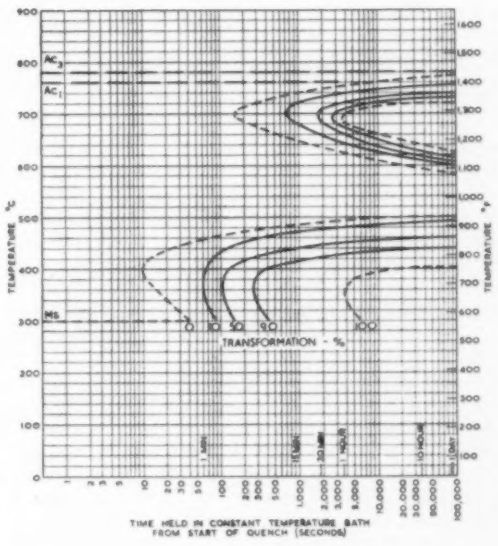


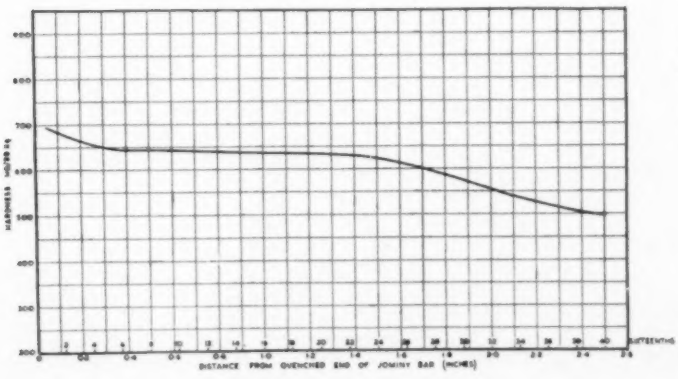
12 (BELOW), **13** (RIGHT)
En 20A—1% Cr-Mo steel (higher Mo) for water hardening

Austenitizing conditions: 875°C (1,607°F); 30 min









14 (ABOVE), **15** (LEFT)
En 20B—1% Cr-Mo steel (higher Mo) for oil-hardening

Austenitizing conditions: 870°C (1,598°F); 30 min

more important requirements—cost and the duties to be performed by the component involved.

En 20A/B

En 20A 1% Cr-Mo (water hardening).
En 20B 1% Cr-Mo (oil hardening).

	C	Si	Mn	Cr	Mo
En 20A	0·2–0·3	0·1–0·35	0·4–0·7	0·5–1·0	0·5–0·8
En 20B	0·35–0·45	0·1–0·35	0·4–0·7	1·0–1·5	0·5–0·9

The diagrams for these steels are shown in figs 12 and 13 and the hardenability data in figs 14 and 15.

In order to consolidate the emphasis of the variation of composition within a certain specification it is well worth comparing the compositions of the actual alloys used in the determination of the T T T diagrams:

	C	Si	Mn	Ni	Cr	Mo	S	P
En 20A ..	0·27	0·13	0·60	0·19	0·74	0·55	0·022	0·030
En 20B ..	0·41	0·28	0·58	0·15	1·39	0·74	0·036	0·028
Increase in En 20B	+0·14	—	—	—	0·65	+0·19	—	—

These very slight changes as shown in line 3 of the table have effected a considerable shift of the transformation curves, greatly increasing the hardenability, and with a gain in maximum hardness from 550 to 700 V D H.

In the case of En 20A (fig 12), in order to obtain maximum hardness, *i e* martensite with no bainite or pearlite, it is necessary to cool from the heat-treatment temperature 850—900°C to below 400°C, the Ms temperature, in less than 1 sec. Thus the alloy must be water hardened. With En 20B (fig 13) on the other hand, the time taken in the cooling medium may be as long as 10 sec isothermally, and probably nearly a minute for continuous cooling if slightly less than full transformation is acceptable. The alloy is therefore oil hardening.

Due to this, martempering could be effected in En 20B since some 30 sec are available for temperature equalization.

Softening treatments are more easily applied to En 20A, as would be expected by a comparison of the curves for the two steels. For the former, continuous cooling is suitable, but the latter requires an isothermal holding temperature of approximately 690°C for at least 3 h to achieve the full effect.

The differences noted are here laid down for a definite purpose; they well illustrate in exaggerated form the warning previously given as to disparity in response from a single specification, owing to variation in chemical composition within the limits set. Further, it is important to observe the degree of improvement in both hardness and hardenability arising from modest increases when these apply to several elements (carbon, chromium and molybdenum) in combination.

En 21 3% Ni steel

C 0·25—0·35, Si 0·1—0·35, Mn 0·35—0·75, Ni 2·75—3·5, Cr 0·3 max.

The T T T diagram of this steel (fig 16) exhibits the bainite nose only—the pearlite nose having almost completely disappeared. Thus the main product on passing through the transformation range quickly, is bainite.

This alloy is relatively easily hardened and is termed a direct hardening steel, giving tensile strengths of 45 to 60 tons ultimate.

The form of the bainite shelf is seen by the horizontal portion of the 50% transformation curve; an alloy cooling through the range inevitably shows partial transformation to ferrite and pearlite which precede the bainitic transformation. If, however, a steel is cooled as in 'normalizing' or more so in 'annealing,' sufficiently slowly when passing through the first part of the zone, say, between 660° and 540°C, reasonably soft products result. Moreover, even the hardest bainite can be softened, if necessary, by tempering, or by sub-critical annealing.

The full softening processes of complete annealing or isothermal annealing are difficult, but fortunately are rarely essential.

These effects are reflected by the hardenability curve (fig 17) with its gradual even descent, suggesting the importance of the rate of cooling.

Higher nickel steels may return to popularity now that the element is not so scarce. The ferrite-strengthening effect enables an excellent combination of physical properties to be obtained at moderate strength even in sections three times the quoted limit of 6 in. Because of the strengthening effect of the nickel on ferrite (including that in the pearlite), a considerable variation of quenching cooling rates is permissible, thus accommodating a wide range of sections.

It is true that in the U S A large sections proved susceptible to hydrogen cracking, but British experience, on the whole, has been more fortunate. Nowadays, higher strength alloys, more creep resistant, such as En 29, have supplanted many heavy section uses for En 21.

En 24

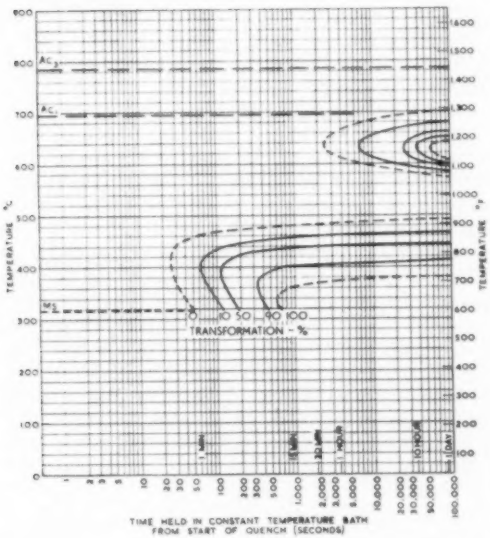
C 0·35—0·45, Si 0·1—0·35, Mn 0·45—0·7, Ni 1·3—1·8, Cr 0·9—1·4, Mo 0·2—0·35.

The use of transformation diagrams as an aid to planning heat-treatment operations is now becoming evident—in this particular case (fig 18) good har-

denability may be expected, but continuous cooling and isothermal annealing are more difficult. This expectancy is confirmed in the hardenability curve (fig 19) which shows high hardness and also its maintenance as the distance from the quenched end increases.

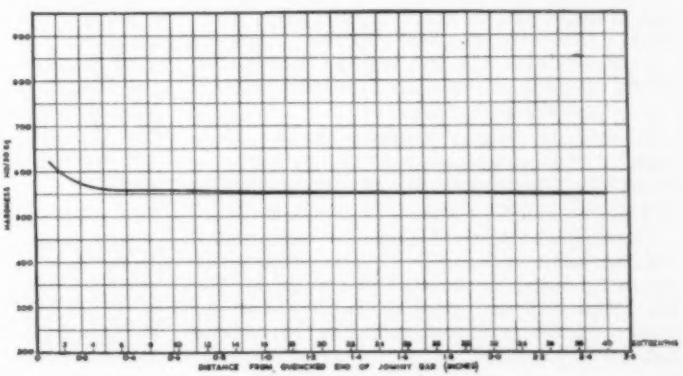
Since annealing is difficult, alternative methods such as softening by tempering or sub-critical annealing are practised.

This useful compromise method is achieved either by first normalizing so that the cooling curve passes through the bainitic shelf, if practical, or alternatively, by carrying through the continuous annealing procedure in the hope that partial transformation will occur during the transit through the pearlitic nose. Sub-critical annealing, which follows, really means a tempering operation performed as close to the Ac_1 temperature as possible, so that the bainite is considerably altered and the resulting coalescence of the finely divided carbides facilitates machining.



20 (ABOVE), **21** (RIGHT)
En 25—2½% *Ni-Cr-Mo steel (medium C)*

Austenitizing conditions: 835°C (1,535°F); 30 min



En 25 2½% Ni-Cr-Mo steel

C 0·27—0·35, Si 0·1—0·35, Mn 0·5—0·7, Ni 2·3—2·8, Cr 0·5—0·8, Mo 0·4—0·7.

The transformation diagram for this steel (fig 20) shows two clearly defined shelves and an examination indicates that the transformation to pearlite on continuous cooling requires times in excess of 24 h. Thus the normal softening processes are almost impossible. On the other hand, hardening is easy and the hardenability high indeed.

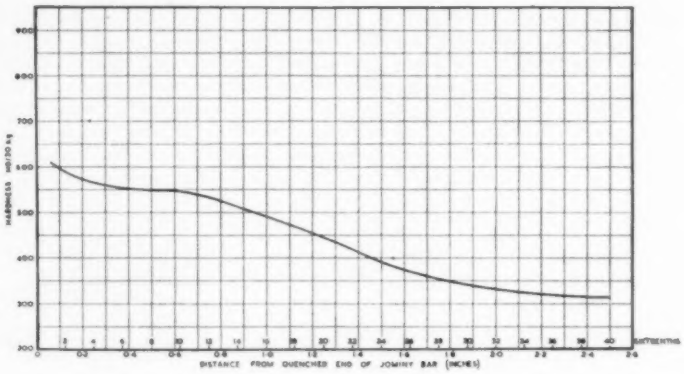
An alloy steel of this composition is necessarily expensive and would be reserved for those cases where high ultimate stress and reaonable ductility are required in a large mass far beyond the En ruling section limit.

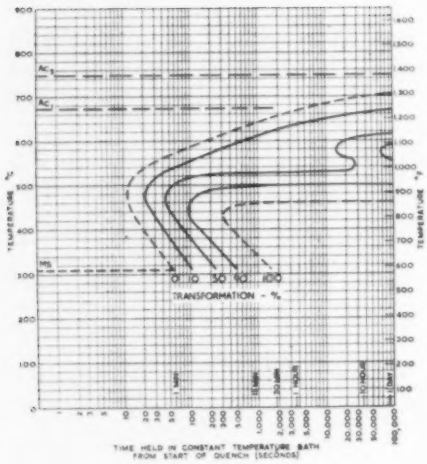
Where a number of large forgings are made together, a heavy furnace load of 20—30 tons would justify an isothermal annealing technique around 650°C, even though it take 2 days; otherwise the procedure of bainitic air hardening followed by sub-critical annealing produces a machineable structure. It is usual to rough machine before hardening. Allegedly this reduces the risk of quench cracking from surface irregularities, forging laps and such-like stress-raisers: really it promotes hardening by reducing the mass and especially by removing the surface scale which offers an insulating barrier.

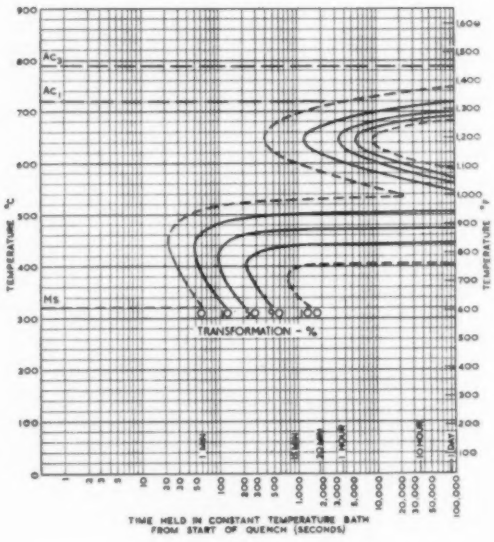
The risks of cracks due to the release of dissolved hydrogen ('snowflakes') is present with this and similar highly alloyed steels of the En series. Precautions by prolonged thermal treatment are required once the ingot structure is broken down. Within a year or two British practice is likely to follow the continental vacuum-casting technique for heats of 60—100 tons, and this will save much valuable furnace time and reduce the incidence of

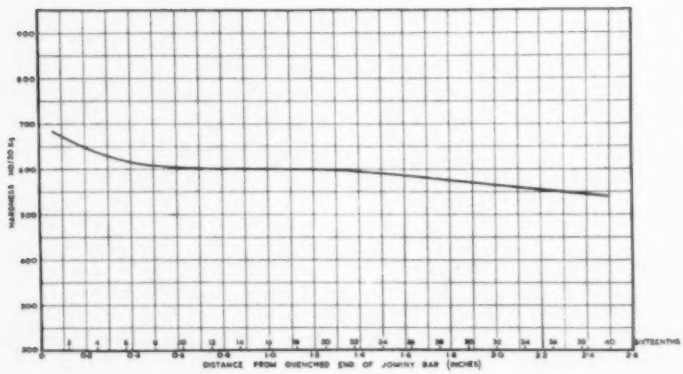
16 (BELOW), **17** (RIGHT)
En 21—3% *Ni steel*

Austenitizing conditions: 840°C (1,544°F); 30 *min*









18 (ABOVE), **19** (LEFT)
En 24—1½% *Ni-Cr-Mo steel*

Austenitizing conditions: 835°C (1,535°F); 30 *min*

Induction heating for forging

P. E. HAMMARLUND and Y. SUNDBERG

One important application of induction heating is in forge shops. Forging machines are increasingly becoming more rapid in operation, thus leading to a growing interest in mechanization. In this connection, induction furnaces have considerable importance both as replacements for and as supplements to conventional fuel-fired furnaces. The following account from Sweden, briefly dealing with the theory of induction heating, has been slightly abridged from the A S E A Journal, 1957

SEVERAL INSTALLATIONS for induction heating for forging have been built and tested and it can be assumed that the induction method will be increasingly used in the future. As is always the case when new methods are being discussed, the disadvantages and limitations must also be examined. These will be dealt with later but, first of all, the basic theory will be examined.

Induction furnaces are always fitted with a coil or loop in which an alternating current causes an alternating magnetic flux. The workpiece to be heated is placed inside and what are known as eddy currents are induced in it. Because of the resistance in the workpiece, heat is developed in those parts through which the eddy currents flow.

For practical reasons, it has proved to be advantageous to divide up the induction furnaces, or, more correctly, the heating loops or coils, into two basic groups, namely the ' axial-field ' heaters and the ' cross-field ' heaters. Fig 1 shows an axial-field heater. In this type, the lines of flux are, in the main, parallel to the longitudinal axis of the heated billet. Usually, the heater has a circular coil, and the billet is placed with its axis approximately in the centre of the coil. The eddy currents in the billet form plane circles at right angles to the longitudinal axis, as will be seen from the figure.

Fig 2 shows a cross-field heater in which the lines of flux run, in the main, at right angles to the longitudinal axis of the billet. Often, the ends of the coil are bent upwards as shown, so that it is possible to push the billet through the heating zone.

The coils are usually wound of copper tubing through which water is led in order to remove the heat losses which occur because of the high currents which must be used. Usually, a yoke made of laminated sheet steel of the same type as in electric transformers is employed, partly in order to reduce the magnetic resistance to the flux, and partly to concentrate the latter at the desired point. Fig 3 shows a cross-field furnace with sheet-steel laminations of this type. It can be seen how the lines of flux run parallel from the one pole of the yokes to the other.

Choice of frequency

The frequency cannot be selected arbitrarily. Fortunately, the choice of frequency for a given workpiece is not critical, and quite a large frequency range does not entail any disadvantages. Generally speaking, the equipment will be dearer the higher the frequency, and therefore it is desirable to keep within the lowest possible frequency range. However, there is a lower limit for the frequency and we shall now attempt to show how this is determined.

As a general principle it can be said that the limit is, in the first place, determined by the dimensions of the workpiece. The smaller these are, the higher the frequency which must be adopted.

The depth of penetration of the eddy currents must be taken into consideration. The currents occur primarily at the surface of the workpiece and the current density in a slab falls off towards the interior, largely in accordance with the equation:

$$S = S_0 \cdot e^{-ax} \quad \text{with } \alpha = 0{\cdot}2\,\pi\sqrt{\frac{f}{1{,}000}\cdot\frac{km}{\sigma}}$$

where

S = current density, A/cm²
S_0 = current density at surface, A/cm²
f = frequency, c/s
σ = the resistivity of the billet, Ω mm²/m
k_m = the permeability of the billet (=1 for non-magnetic objects)
x = the distance from the surface in cm

If we insert in equation (1) $x = 1/\alpha$ we obtain

$$S = S_0/e = S_0 \cdot 0{\cdot}368$$

Within a surface layer having the thickness

expensive failures which are sometimes only revealed during heat treatment.

En 25 is a favourite material for certain components of drop-forging plant, *e g* sow blocks, piston rods and the rams of power-assisted hammers. A large example of the latter, weighing well over 5 tons, gave physical test figures from the thinner top section as follows:

	U S	Y P	E%	R%	Izod
Length ..	60·4	52·8	20	53·6	47, 44, 45
Transverse ..	60·6	53·0	17	43·6	35, 35, 36

This provides the extreme hardenability demanded by such masses.

En 29, which replaces the nickel by a higher chromium content of 3%, also satisfies these requirements, especially when creep resistance at moderate temperature is needed.

The general effect of nickel, chromium or molybdenum in combination for high hardness and hardenability may be utilized to produce even greater strength, by increasing the carbon content as in En 26, and the culmination of this process is found in En 30B, where larger amounts of nickel and chromium more than balance a slight reduction in molybdenum, so that 100 tons ultimate stress is obtainable up to 2½ in. thick, even by air hardening, and in greater sizes by oil quenching and tempering. This steel is favoured for moulds in which certain erosive thermosetting plastic articles are formed, demanding high hardness. Fine detail requires reasonable machineability yet equally precludes the undue risk of quench cracking and distortion where sharp corners and varying projecting sections are inescapable. Here the capacity for air hardening up to 80—90 tons ultimate stress in relatively large sections is invaluable.

In the 50—75-ton range, however, the same general isothermal characteristics have been employed with the laudable object of producing low-alloy combinations in which much existing scrap, already containing all three elements, might be usefully employed. En 100 and 110 resulted, the former extending the economy by using a relatively high manganese content up to 1·5%.

No complete detailed description of all the steels intended for subsequent surface treatment is possible in a short article, but two series should be mentioned.

The various effects of increased hardenability and hardness conferred by alloy additions are repeated in compositions intended for case hardening. Nickel, if desired, may be used, but the carbon content is limited to 0·25% to preserve core ductility.

This general progressive pattern is maintained for nitriding steels except that nickel is avoided, beyond small amounts, since it restricts the process, whereas an aluminium content, sometimes employed, increases the potential. Carbon, too, may be usefully increased, up to 0·5%, where 90-ton core strength is demanded. The essential factor here is that the pre-nitriding heat treatment shall employ a tempering temperature somewhat above 500°C so that the subsequent lengthy process will not substantially change the core characteristics already established.

Conclusion

Transformation diagrams and Jominy hardenability curves provide a useful guide in planning heat treatment, and if due allowance is made for such variations as may be encountered within a particular En specification, good results can be obtained.

The transformation characteristics vary with austenitizing conditions and also with such factors as the initial grain size and the 'as received' condition of the metal. Since the diagrams were compiled from data obtained with very small specimens, generous allowances should be made in practice, in particular when very large sections are being dealt with.

Such treatments as isothermal annealing, austempering, and martempering may be directly related to the diagram concerned, and since the effect of continuous cooling is to move the curves downwards and to the right, the isothermal curves for the beginning of the transformation may be adopted for reference, the degree of displacement being considered as a factor of safety. In this way such treatments as continuous annealing, normalizing, hardening, etc, may be reasonably determined.

As a result of the benefit already conferred in practical treatment, the next stage is now under consideration by B I S R A and several research establishments. Before long continuous cooling curves for a number of En steels will be available. These will depict in simple form the transformation products obtained for various sections at differing rates of cooling, thus further assisting in the shop-floor application of metallurgical principles to heat treatment.

E. H. Jones (Machine Tools) Ltd announces the completion of new premises at 48 High Street, Edgware. Telephone Edgware 4488/9. The accommodation consists of a large warehouse for used machines and a well-appointed showroom is equipped for working demonstrations and provision has been made for the introduction of a spares service for CVA automatics and dieing presses.

Temperature conditions

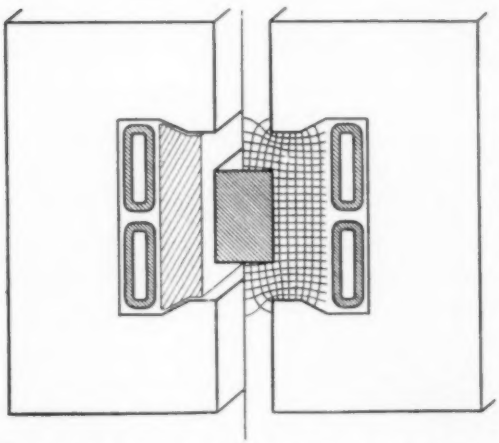
The importance of the choice of frequency is demonstrated in fig 5, which shows how the temperature is distributed in a bolt, which is heated at different frequencies, but with the same high-frequency input to the furnace coil. In the case of the bolt on the left, it can be seen how the temperature is distributed inside the bolt at the various times 1, 2, 3 and 4, when the frequency is relatively high. It is heat conduction which primarily determines the temperature in the centre since the energy is developed almost entirely in the surface layer. The final result is a fairly uneven distribution of temperature. However, it usually does not take long before it has evened itself out.

In the case of the bolt in the middle, the temperature distribution is shown when a somewhat lower frequency is selected, which is, however, such that the degree of efficiency is still quite good. Here, the depth of penetration is greater, for which reason heat conduction alone does not have to be relied on for bringing the central parts of the bolt up to the desired temperature. At the end of the heating process which is assumed to have the same duration as for the bolt on the left, the temperature distribution in the bolt is rather more even than in the first case.

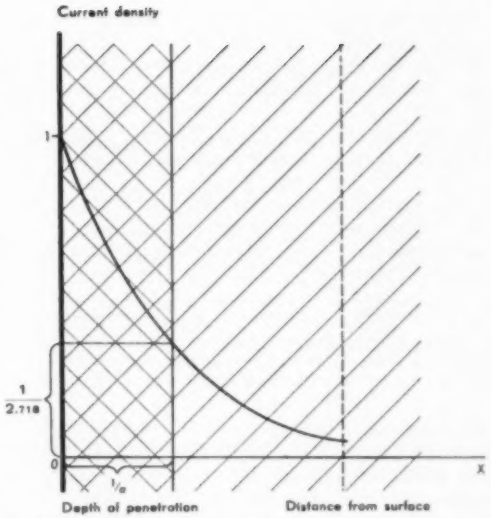
On the right, the conditions are shown if an excessively low frequency is selected. Here, the degress of efficiency is poor, and the desired temperature cannot be reached at all, even though heating be carried on for a very long time.

Power requirements and efficiency

For heating a workpiece, a certain nett power is required, depending upon:



3 *Cross-field heater for bars or slabs fitted with yokes for the magnetic flux*



4 *Current penetration into a billet*

(*a*) the specific heat of the material;
(*b*) the dimensions of the heated part of the workpiece;
(*c*) the initial temperature and the final temperature;
(*d*) the heating period.

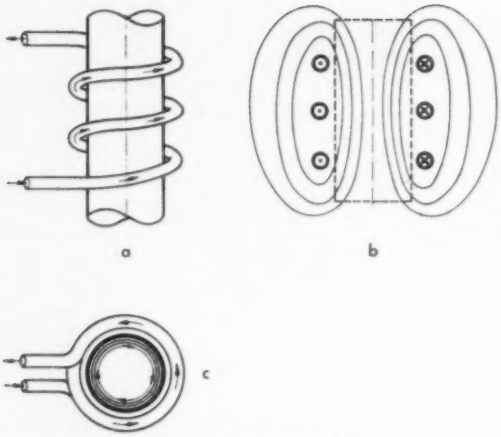
This nett power can be determined most rapidly with the aid of curves which have been drawn for the energy content as a function of the temperature. Some of these are shown in fig 6 for a number of the more common metals.

A certain amount of power in addition to the nett power must be applied to the workpiece in order to cover the losses due to radiation, conduction and convection.

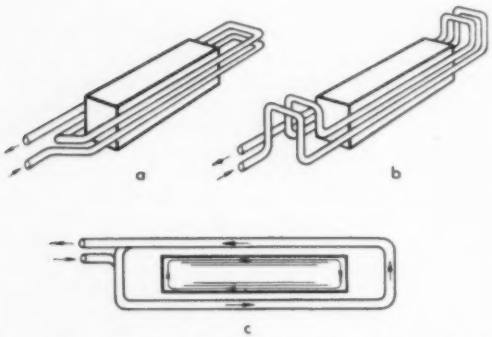
The losses in an induction furnace are partly losses in the furnace coil and in the laminations, if any, and partly heat losses from the heated workpiece. As far as the losses in the furnace are concerned, as has already been stated, they are so high that they have to be removed with the aid of cooling water. The losses are proportionately greater the larger the surface of the coil, and it is therefore usual to attempt to save space between the workpiece and the coil as much as possible.

The losses in the laminations can, generally speaking, be kept down so much that they can be neglected as compared with the losses in the furnace coil.

The heat losses in the workpiece through radiation, conduction and convection are often very large. At the temperatures normally occurring, it is usually the losses through radiation which are the



1 *Axial-field heater (a) side view of heater with workpiece, (b) diagram of magnetic flux, (c) heater from above showing directions of current flow*



2 *Cross-field heater (a and c) simple form of heater, (b) heater with coil ends bent upwards*

$x = 1/\alpha$, 86·5% of the heat is developed, while only 13·5% is developed further in. Therefore, $1/\alpha$ is usually known as the penetration depth

If, for example, the frequency 4,000 c/s and a normal field strength for iron are selected, a depth of penetration of 0·1 cm for the temperature area where the iron is magnetic, and 0·9 cm for the area where the iron is non-magnetic (above the Curie point) is obtained by the above formula. There is thus a considerable difference in the depth of penetration for magnetic and non-magnetic material.

Fig 4 shows a curve in accordance with the above-mentioned equation, from which it may clearly be seen how the current density decreases from the surface inwards in a material which is in the magnetic alternating field. It will be seen that the layer which is defined by the depth of penetration conducts the greater part of the current. It is now possible to understand that there is a lower limit for the frequency in accordance with the following simplified argument. If one imagines a slab with a thickness b with the current running forwards on the one side of the slab with a depth of penetration of $1/\alpha$ and, as is usually the case, returning along the other side of the slab with the same depth of penetration, it will be seen that the two zones of penetration at the sides of the slab must not encroach upon each other. If they did so, the currents would cancel each other out so that no development of heat could arise. Thus, a condition is that the depth of penetration $1/\alpha$ should be less than half the width of the slab, that is to say $b/2$. In spite of this, there will be a certain amount of heating, even though this condition is not fulfilled, but at the price of a low degree of efficiency.

Table I shows the frequencies calculated in accordance with the formula quoted above for different slab thicknesses. Corresponding values have also been worked out for bolts with the diameter d. The formula for bolts is somewhat different, but the principle is the same. The table has been worked out for steel above the Curie point, that is to say, for non-magnetic material.

It should be pointed out in this connection that the frequency values given in the table should be regarded as minimum ones, since values lower than these would not give effective heating for the various dimensions. It is of interest to note that when a frequency of 50 c/s is adopted, bolts which have a smaller diameter than 220 mm (8·7 in.) will not be effectively heated if the material is non-magnetic iron. Unfortunately, in most practical cases, high frequency must be used. At those temperatures where the iron is still magnetic, the conditions are somewhat better. There, it is possible to heat bolts with a diameter almost down to 50 mm (2 in.) with a frequency of 50 c/s.

TABLE I *The lowest frequencies for various workpiece dimensions (non-magnetic steel)*

Slabs	b cm	0·5	0·7	1	1·5	2	3	4	6	8	10	15
	f c/s	48,600	24,800	12,160	5,400	3,040	1,350	760	338	190	121	50
Bolts	d cm	0·5	0·7	1	1·5	2	3	4	6	8	10	22
	f c/s	97,200	49,600	24,320	10,800	6,080	2,700	1,520	676	380	243	50

which causes little scaling, even when the air has full access. By this means, material is saved and, of course, tools also. The rapid heating makes it possible to limit the time the billet is in the upper temperature range, thus preventing grain growth in the material to a considerable extent. This may simplify the heat treatment after forging.

The rapid heating makes possible the partial heating of workpieces which may be an advantage both from the point of view of power and for other reasons.

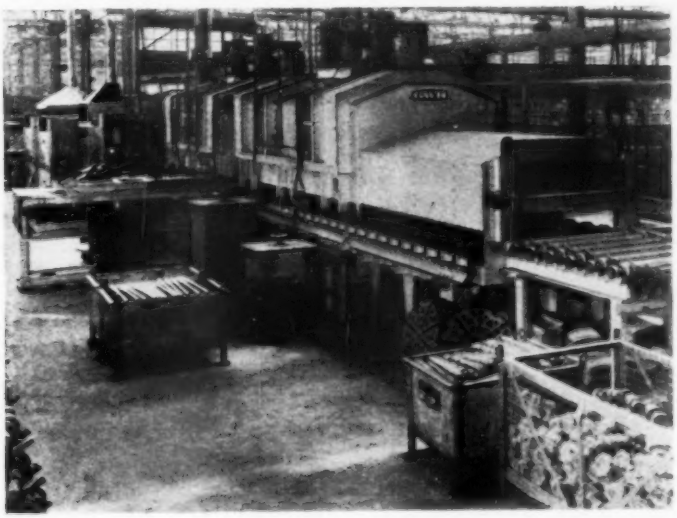
The energy is developed inside the workpiece and therefore the condition of the outside is of no importance. No leads are required, the transfer of energy taking place through space.

The heating temperature as between workpieces is extraordinarily uniform in the case of normal dimension tolerances of the pieces. If desired, it is quite simple to arrange pyrometer control so that the heating operation is terminated when the set temperature is reached.

The heaters are compact and require little space. They can often be placed in a production line direct.

They open a wide field for automation. Magazine feeding is simple to arrange and it is possible to exploit automation to the utmost. If suitable, the heater can even be built into the forging machine.

The heater is ready for use immediately after it has been connected up. All running up time is eliminated.



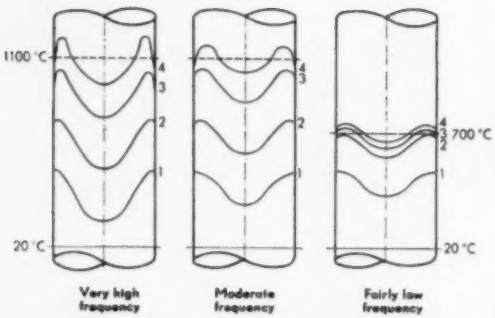
View from discharge end of G W B roller-hearth furnace

Heat treatment at Jaguar Cars Ltd

THE ELECTRICALLY-HEATED roller-hearth furnace shown above was supplied by G.W.B. Furnaces Ltd., Dudley, to Jaguar Cars Ltd. and is a dual-purpose furnace used for cyclic annealing and stress relieving a variety of components. Partly machined forgings such as crank shafts and gear blanks are stress relieved at temperatures varying between 550 and 650° C. and brought down to approximately 200° C. in the 8 ft. 6 in. long air forced-cooling chamber. Welded components of a heavy nature are normalized by slow cool from 900° C., whilst gear forgings are cyclic annealed by heating at 950° C., cooled to 550° C. and reheated to 650° C. before being finally discharged from the furnace. The various types of heat treatments outlined above are made possible by the furnace design, which can be regarded as being one installation in two sections. Commencing from the entrance end there is a short loading section leading into the high-temperature (950° C.) furnace, immediately after it is situated a 2 ft. 6 in. length where forced draft cooling takes place, and is then followed by a 10 ft. length at the lower temperature; finally, as a continuation of the furnace, there is a cooling chamber. When the full cyclic annealing is required, the components pass through the whole installation, whilst in the case of stress relieving, the parts may be inserted either at the starting end of the furnace and given a long-term anneal by passing through both chambers, maintained, of course, at the low temperature; or, alternatively, they may be inserted through the side door of the furnace at the point where the short forced-cooling section divides the high- and low-temperature heating zones.

The heating is divided into four independently controlled zones, two for the high- and two for the low-temperature sections. A total rating of 165 kW. is contained in these four zones, each of which is fed through a transformer which has four tappings so that, when required, the rating can be reduced down to as little as 75 kW. Two paddle-type fans for providing convective air currents are fitted in both high- and low-temperature sections,

The dual-purpose nature of this installation and the compactness in design enable both the heat treatments to be carried out in a considerably smaller space than would otherwise be necessary.



5 *Effect of frequency on the temperature distribution in workpieces which are magnetic at low temperatures. 1, 2, 3, and 4 indicate distribution of temperature at various times*

dominant ones. If there is no heat insulation between the water-cooled, and thus cold, coil and the actual workpiece, radiation from the latter occurs into cold surroundings, and since the effect of radiation increases with the absolute temperature to the fourth power, the amount can be quite large at temperatures round about 1,000°C. It is generally not practical to arrange heat insulation in the furnace, because of lack of space (from the point of view of efficiency it is essential to keep the distance between the coil and the workpiece as short as possible), and because one of the major advantages of the induction furnace would then be invalidated, namely that the furnace is ready for use without any previous running-up period for heating the insulating material.

The efficiency of induction furnaces is therefore not particularly high. The total degree of efficiency of a normal installation is of the order of 50%. If it is desired to heat a piece of steel up to forging temperature, that is to say, to apply about 230 kWh/ton to it, then 460 kWh/ton is required from the supply network. This is the case with continuous running. However, if there are interruptions and if the furnace is not switched off when not actually in use, or if the insertion of workpieces, the heating time and the furnace current are badly co-ordinated, no-load losses will also occur, whereupon the power consumption will be considerably increased.

Design of heaters

Induction heaters can be designed and used in many different ways, depending on the size of the workpiece, the frequency, and the unevenness of temperature which can be tolerated. The heating time for the workpiece may vary from a fraction of a minute to more than 5 minutes. Clearly, it will often be the case that several workpieces must be heated at the same time, which can be done either by a number of parallel single-piece heaters which are fed with the pieces at a suitable speed, or by means of a multi-piece heater in which the pieces are fed forward either in steps or continuously.

The decisive factor in determining the design of the heaters is the arrangement of the transport device for the workpieces. Several problems arise in this connection. The coil must enclose the workpiece as closely as possible for which reason there is not much space available for transport devices. Even so, it is essential to have robust feeding devices which do not require much maintenance.

Advantages and disadvantages

Finally, the more important advantages and disadvantages associated with induction heating for forging will be dealt with. The disadvantages will be taken first.

Capital costs are high, in most cases considerably higher than for furnaces fired by oil or gas

They are not suitable for cases where the rate of forging is irregular from one workpiece to the next.

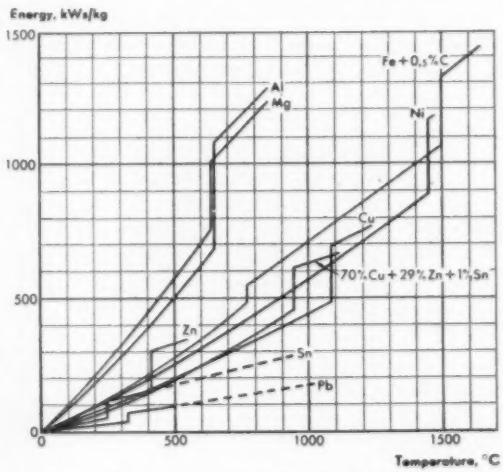
Neither are they suitable for cases where small numbers of different series of pieces have to be forged, since induction heaters have to be designed in order to fit in well with the shape and dimensions of each workpiece.

The last two disadvantages, together with the high capital costs, naturally limit the scope of induction heating for forging.

The following advantages form a basis for judging when it pays to use induction heating.

Working conditions are good because the heater is always cold and gives out neither gas nor smoke.

An extremely high rate of heating is obtained



6 *Curves showing energy as a function of temperature for various metals and alloys*

The overall architectural plans were drawn up by Mr A. Dangleterre, leaving ample free space for future constructions or installations. Rough-labour and road-building began in 1956 and was completed rapidly enough to allow the construction work proper to be started early in 1957.

The plant comprises four shops on the north-east part of the site (two assigned to ores, one to hot metal, one to the shop), and in the south-west part the laboratories, the administrative building, and the staff house.

Ore plant. The block assigned to ore study comprises two adjacent shops, bright and roomy, each equipped with a 10-ton overhead crane, of 15 metres span-width, and flanked on the western side by a one-storey building.

One of these shops is intended for ore-dressing. The northern portion, partly separate from the rest, is equipped to accommodate and crush (down to grain sizes of 60 to 100 mm) batches of ore weighing several tons. The products, taken up in 3-ton skips, can then be sent either to storage bins (4 hoppers of 30-ton capacity), or to the ore dressing devices. The different operations of preparation, drying, crushing, screening, can be carried out and studied in continuous circuits having an output of several tons per hour.

In the south end of the shop are grouped various prototype devices, in process of development or construction, for the vacuum treatment of very finely divided ores.

The other shop is mainly assigned to beneficiation and agglomeration testing. The beneficiation equipment includes: Ore-dressing, by dry and wet processes, on a small scale (outputs not exceeding some hundreds of kg/h), and gravimetric and magnetic beneficiation devices (outputs from laboratory-scale to 5 t/h).

The sintering section comprises a large installation including vats of various dimensions (square vats of 30 cm side, a circular vat of 10 cm diameter), devices for mixing preparations, and many measuring instruments. Part of the shop is reserved for coke testing.

On the first floor of the side building, there are offices, while on the ground floor are installed the blowers of the sintering plant, various laboratories grouping the small laboratory-scale devices, and sanitary facilities.

Hot-metal shop. The shop designed for hot-metal testing is equipped with a 20-ton overhead crane, of 18 metres span-width, with a 5-ton auxiliary hoist, and flanked by two one-storey buildings.

For iron or scrap melting, a 6-ton arc furnace has been installed in the centre of the shop, on a working platform set 3 metres above ground level. The furnace is of the type having a tilting roof, mechanized charging, and automatic hydraulic electrode adjustment; it makes it possible to melt a 4-ton iron charge in less than 1½ hours (power: 3,000 kVa; primary voltage: 5,500 V; eight secondary voltages, ranging from 220 to 87 V).

Between the unloading platform and the furnace, a concrete block, called the testing area, temporarily accommodates the metallurgical equipment. A system of easily removable wooden floors, on the block, facilitates working conditions around the apparatus. At present, a steel-plant converter of 6-ton capacity is being assembled on the concrete block, for iron refining purposes. The retort is handled by means of an electrical tilting mechanism. A large door, located in front of the testing area, can be opened during the refining operation to allow the removal of fumes from the building.

The western shop houses stock rooms, offices and sanitary installations. At the southern end of that building, in a special room, are installed the high-frequency furnaces which have been transferred from Saint-Germain-en-Laye (a conventional furnace of 300 kg capacity, and a vacuum melting furnace of 50 kg capacity).

In the eastern shop, there is the compressor-room housing a 830 h p blower, a generator set for the high-frequency furnaces, and the compressor feeding compressed air to the whole plant (power: 150 h p).

Workshop. The workshop is equipped with a 10-ton overhead crane, of 15 metres span-width. The essential function of the section is to assure the general maintenance of the pilot-plant and to prepare the testing and measuring equipment.

In the central part of the shop are installed the machine-tools required for metal machining, boiler work, and the electrical maintenance section. Room has been reserved for a testing and assembling platform. An electronics laboratory and a technical studies office are also incorporated.

Power and other supplies. Electrical power is conveyed to the pilot-plant through a 3-phase 63,000-volt special line, installed by Électricité de France. Current is transformed at a sub-station and distributed into the various buildings through 5,500 volt underground cables. Three transformers supply the 220-127-volt current. An emergency 5,500-volt line is connected to the Sidélor mains.

Gas is tapped from the 45 hpz East Paris feeder of Gaz de France. The gas is expanded at pressures of 3 hpz and 100 mm water.

All the water needed by the pilot-plant is supplied by two wells. It is potable. An automatic pumping station forces it in a ground tank of 150 m^3 capacity, from where it is distributed under a pressure of 4 hpz. Waste water is discharged into a nearby brook, the Billeron, after having been purified and neutralized.

New French iron and steel research centre

IRSID pilot-plant at Maizières-lès-Metz

IRSID WAS FOUNDED by a decision of the 'Comité d'Organization de la Sidérurgie ' in 1944, and came into being in 1946. It is a professional organization linked to the ' Chambre Syndicale de la Sidérurgie' and, since the creation of the European Coal and Steel Community, has been financed by a voluntary contribution from the iron and steel industry, proportional to the tonnage shipped yearly by each of the member companies. IRSID administration is ensured by a Board of Directors, Mr H. Malcor having been president since the inception.

In 1947, IRSID began the construction of the large up-to-date laboratories essential for its activity. Those laboratories, built in the countryside, at Saint-Germain-en-Laye, close to Paris, under the supervision of Mr G. Delbart, were inaugurated in 1952.

Besides the research work carried out at Saint-Germain-en-Laye, many test programmes are carried out in the iron and steel plants themselves, as well as in pilot-plants, some of them entirely equipped by IRSID, such as the one at Saulnes for the study of ores, and others in cooperation with French or foreign organizations. On account of the continued development of its industrial research work, IRSID decided in 1955 to set up a large pilot-plant in Eastern France, at Maizières-lès-Metz. The construction of that plant is now being completed under the supervision of Mr M. Allard, general manager of IRSID.

The new pilot-plant

The purpose of the pilot-plant at Maizières-lès-Metz is to give the Industrial Departments, with far greater facilities than were available at the Saulnes pilot-plant, the possibility of processing, outside the commercial iron and steel factories, tonnages sufficient to allow full-scale methods to be extrapolated from the results. The equipment includes apparatus formerly the property of IRSID, as well as new items. Present equipment is intended primarily for the study of iron ore, and hot metal treatments. The initial work was carried out seven years ago by Mr L. Coche, then the head of the Ores Department.

The plant has been built in the southernmost part of Maizières-lès-Metz, a small commune 4·35 miles north of Metz, on a 29-acre site provided with a railway side-line. This location has the dual advantage of being in the very midst of the Lorraine basin, close to Luxembourg and the Saar, and in the neighbourhood of a big city.

cold and hot states, and research on the behaviour of ferrous metals in service. It has thus an intermediate status between the laboratory research departments and the industrial departments, and keeps in close touch with the factories and steel users.

The major part of the research work is carried out at Saint-Germain-en-Laye. The laboratories have at their disposal microscopes, equipment for supersonic detection, radioactivity counters, microphotometers, etc., as well as heat treating furnaces, fatigue testing machines, equipment for creep tests and other mechanical tests, equipment for the study of transformations in steel.

Investigations. Miscellaneous studies employing radioactive tracers, examination of dendritic segregations, determination of various elements, etc.

Development of a gammascopic device, permitting continuous inspection of semi-finished products in the hot state.

Use of special metallographic techniques making it possible to reveal austenite grain boundaries, as well as fine magnetic constituents.

Survey of the properties of boron steels, and development of their production on a commercial scale.

Study of the properties of manganese austenitic steels.

Theoretical and practical studies on brittle fracture of steel. Participation in the studies undertaken within the framework of the Institut International de Soudure (International Welding Institute) with a view to determining acceptance ranges of the impact and Van der Veen tests for the receipt of steels of welding quality.

Theoretical and practical tests on steel fatigue (Contemplated co-operation with BISRA).

Studies on the possibility of use of rimming Thomas (basic Bessemer) and open hearth steels in welded structures.

Study on the properties of various very high strength low alloy steels.

Theoretical and practical studies on creep-resisting steels used in thermal power plants.

Working out the TTT curves of French steels in isothermal and continuous cooling conditions.

Improvement of investigation techniques (micrographic reagents).

Study of railway rails, tyres and enamelling sheet defects.

Study of non-destructive methods for the detection of defects in iron and steel products. Inspection by supersonic and electro-magnetic means, improvement of methods and development of industrial devices for the automatic and continuous testing of various products: rails, tyres, billets, plates and sheets.

Physics department. The Physics Department performs work in certain fields of physical investigation requiring specialized personnel and equipment, for the other IRSID departments, and even for steel plants.

Secondly, it carries on basic studies on some major problems of the physics of metals, having more or less immediate practical applications.

The laboratories of the department are equipped with up-to-date instruments, such as a 'Trüb Tauber' electron microscope and a 'Trüb Tauber' electron diffractograph, a 'Norelco' x-ray automatic spectrometer, an 'ARL' grating spectrograph and a number of micromachines. Particularly worthy of mention are an electron probe microanalyser (Castaing-Onéra system) and a hysteresimeter built by IRSID for extremely high temperatures (Patent No. PV 692,236).

Investigations. Study of martensite decomposition and of austenite stabilization.

Structure and properties of grain boundaries.

Studies on internal friction and anelasticity. Use of the hysteresimeter built by IRSID for high temperatures.

Study of surface oxidization of metals, and of scale formation.

X-ray study of steel sheet structure, relation with drawing properties.

Theoretical study of the creep process (polygonizing).

Study of mild steel ageing.

Study of the mechanism of brittle fractures, and interpretation of impact test phenomena.

Micro-mechanical properties. Magnetic tests in tension, compression and fatigue.

Application of the electron microscope to the detection of minute inclusions, to the study of fumes (from the basic Bessemer converter, for instance), and to micro-fractography.

Use of the electron probe micro-analyser; application to the analysis of segregations and precipitates in steels, to the working out of equilibrium diagrams, to the study of diffusion in metals, and to local analysis of ores.

Quantitative determination of various mixtures by means of x-rays.

Development of spectrographic methods for the analysis of trace elements in steels, and for the analysis of slags. Design of a vacuum spark spectrometer.

Study of pyrometric methods (thermocouples and optical pyrometers).

Compressed air, at a pressure of 7 hpz, is supplied to the whole plant by the compressor in the hot metal hall, at a flow rate of 20 Nm^3/minute.

The shops are heated by means of propelled air supplied by fuel oil-fired 'caloriblocs', and the other buildings are provided with central heating by water circulation boilers equipped with fuel oil burners.

Laboratories. The laboratories of the pilot-plant are intended to carry out all the routine investigations, by chemical or physical methods relating to iron ores, metals and other metallurgical products. Fundamental studies are still reserved for the laboratories of Saint-Germain-en-Laye.

On the ground floor are located a large room for sample preparations, a room for heavy media separation of iron ores, a chemical laboratory, and stock-rooms for chemical products and glassware. Rooms are also reserved for determinations by physical methods.

The first floor is in the main occupied by a large chemical laboratory with 10-work-bench places. On either side of the laboratory are installed a wash-room, a balance-room, a room for colorimetry and the offices of the head of the Analytical Department.

Administrative quarters. The administrative building contains most of the pilot-plant offices, including those of the technical departments carrying out the industrial tests. This has been done in order to promote contacts between specialists of different disciplines. The ground floor is occupied by the managerial officers and by various offices of the industrial sections (agglomeration, fuels, blast-furnaces, melting).

On the first floor are located the offices of the specialists dealing with iron ore beneficiation, as well as those of the geologists, both of IRSID and of the 'Chambre Syndicale des Mines de Fer', who are conducting together a comprehensive investigation of Lorraine iron ores. Several laboratories are equipped for mineralogical studies.

The library and the room containing the collection of geological specimens are also located in that building.

Staff house. This building contains the staff restaurant, as well as the rooms required to accommodate guests.

On the ground floor are found the restaurant room accommodating 200, a reception room, living-room, dining-room for the guests, the kitchens and the flat of the house manager, and two bedrooms.

On the first floor there are 13 bedrooms, each with private bathroom, 12 of which can be joined in pairs to make up small suites when engineers are accompanied by their families.

In the basement there is a staff rest-room on an English courtyard.

In addition to the two main groups of buildings there are a power sub-station, gas station, water pumping station, stock-room for acids, gatekeeper's lodge.

Staff housing. To house the staff, IRSID applied to the 'Union for Construction in the Lorraine Basin'. Its consulting architect, Mr M. Doignon-Tournier has been put in charge of the construction of a number of buildings.

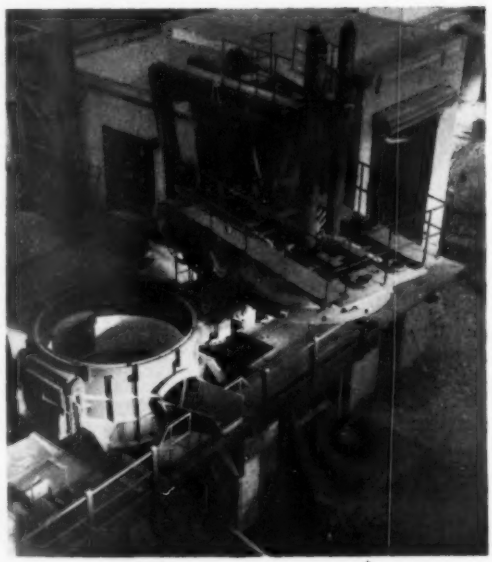
Thirty-two flats have been built at Maizières-lès-Metz by the 'Société Civile Immobilière du Jaseron' with the help of 'Crédit Foncier de France' and the cooperation of the municipality of Maizières-lès-Metz. In addition the 'Société Civile Immobilière de Semécourt' have built 25 flats at Metz-Queuleu and four cottages at Semécourt.

Operating since the beginning of 1958, the pilot-plant at Maizières-lès-Metz employs 110 members of IRSID, 28 of whom are trained personnel.

Some current IRSID research

The following selection of items on the research programme will give some idea of the scope of the field relevant to this journal.

Metallography. The task of the Metallography Department is more extensive than might be judged from its name. It is in charge of the technical studies on the properties of steel and pig iron in the solid state, which comprise not only metallography proper, but also mechanical tests in the



6-ton arc furnace for iron or scrap melting

NEWS

Continuous rolling of stainless steel

EXTENSIVE ADDITIONS to the Sheffield works of Shepcote Lane Rolling Mills Ltd, a subsidiary company of Firth-Vickers Stainless Steels Ltd, have now been completed at a cost of more than one and a half million pounds, making this plant the largest and most modern of its kind in Europe and increasing its production by more than 50%. The mills can now produce up to nine miles of stainless steel strip of average gauge and width per day.

The main alterations have been to the hot-rolling mill. This, in its original form, rolled slabs of up to 1,400 lb down to 60 ft long coils of stainless steel strip. Due to the very critical temperature requirements of stainless steel, it was not possible to roll lengths greater than this and to obtain a coil sufficiently long for economical processing, several smaller coils had to be carefully matched and welded to make up the 3 to 5 ton type required.

As a result of the alterations, the hot mill is now capable of handling slabs of up to 8,000 lb weight and of rolling stainless steel strip, up to 41½ in. wide, in lengths of 350 to 400 ft in gauges as low as 0·10 in. Conservation of the heat needed for rolling the longer coil has been achieved by use of the hot Steckel principle of rolling by means of coiling furnaces installed on either side of the hot finishing mill.

Other recently completed alterations to the original plant include the addition of a third softening and descaling line and a new skin-pass mill. Modifications have also been made to the slab-grinding equipment and the strip-grinding line.

£2½ million sinter plant for Workington

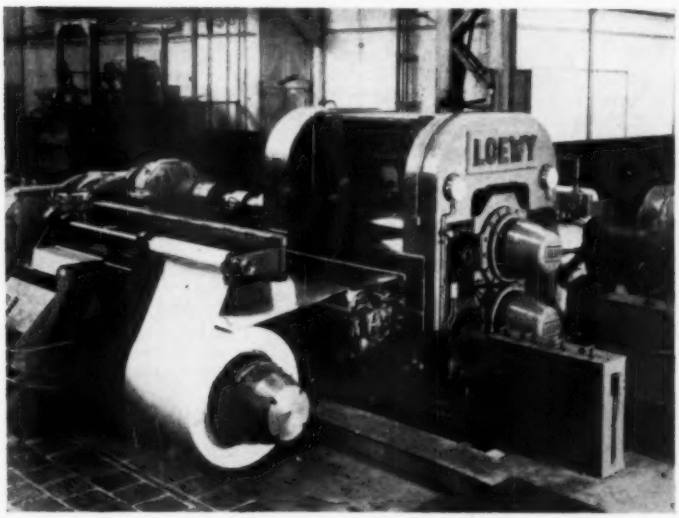
Workington Iron and Steel Company, a branch of the United Steel Companies Ltd, is to spend £2½ million on a new single-strand continuous sinter plant. Designed to produce 12,500 tons of self-fluxing sinter per week for the company's blast furnaces, the plant is being supplied by Head, Wrightson & Co Ltd, and is expected to be in operation by the end of 1960.

In the material storage building, which will form part of the plant, stock bays are to be provided for approximately 40,000 tons of ore fines and material bins will be arranged in line parallel to the storage yard. Conveyor belt systems will bring the fines to the stock bays and material bins, and an overhead grab crane will transfer the ore from the bays to the bins when necessary. Coke breeze, which is also required in the sintering process, will be pulverized at the existing coke-oven plant and a crusher house for crushing limestone is to be built adjacent to the material storage building.

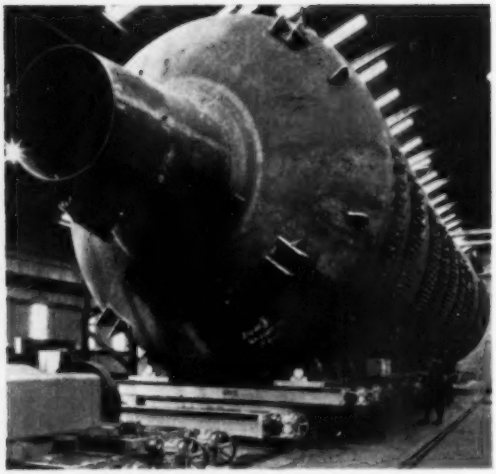
Sinter mixture materials will be fed on to a gathering belt by 9-ft diameter rotary feeder tables fitted with Ward Leonard control for speed adjustment, but in addition the coke feeders will have an independent speed control. After primary mixing in a twin paddle rotary drum mixer, the mixture will pass to a surge hopper, fitted with a variable speed rotary feeder table. Finally, it will go through a pelletizing drum prior to distribution on the strand. Mixed blast furnace and coke-oven gas will be used for ignition.

The 72-in. wide sinter machine will have an effective length of 168 ft over 28 wind-boxes, the strand being equipped with pallets having 14-in. high side plates. The variable speed range of the strand will be from 45 to 170 in./min. Gas from the wind-boxes will be collected in a straight dust collector wind main of increasing cross-sectional area, the last 90-ft long section of which will act as a dust-settling chamber.

Discharged sinter will pass through a breaker with 6-in. knife spacings to a Schenk vibrating screen. By means of a variable speed feeder, the + ¾-in. sinter will be fed to a Lurgi Frodingham circular cooler with a designed capacity of 100 ton/h. The pallets in this cooler will discharge the sinter into a hopper for transfer



Among the recently completed alteration to the original plant at Shepcote Lane Rolling Mills Ltd is this new Loewy two-high skin-pass mill



Heat exchanger for nuclear power station

Transport by sea to Bradwell

THE FIRST HEAT EXCHANGER for the Bradwell Nuclear Power Station was launched on May 16 from the Teesdale Iron Works of Head Wrightson & Co Ltd at Thornaby-on-Tees.

On account of their size, the pressure vessels can not be delivered in one piece by road or rail, neither would it be possible to deliver the vessels broken down into rings (as was done at Calder Hall) for the same reason. It would be possible to deliver them broken down piece-small, *i e* each plate separately, but the complexity of operations and the need for specialized supervision in the assembly on site away from the works made it advantageous to look for another alternative.

The geographical position of the fabricating shops and the site of the power station both being situated on rivers on the East Coast appeared to offer a solution, and it was considered that by completely fabricating these vessels in the works under strict control, launching them into the river, towing and hauling out of the river at site was the best answer to the problem.

At the Bradwell Site a concrete slipway has been built, down which runs a road low loader. The vessels are floated into position above this vehicle and as the tide falls the weight of the vessels is taken on the vehicle. This is then hauled out of the river with the aid of powerful tractors and taken to the power station site under the Goliath crane for lifting into its final position.

Heat-exchange system

Bradwell Power Station is being built by the Nuclear Power Plant Co Ltd who were responsible for the basic design. The 300MW station will have two nuclear reactors which will generate heat to provide steam from twelve heat exchangers. The detailed design of the heat exchangers was done by Head Wrightson & Co Ltd in collaboration with Clarke Chapman & Co Ltd, another member of the Nuclear Power Plant Co Ltd.

The heat exchange system consists of three vessels positioned on two sides of each reactor to give a compact arrangement totally enclosed by a glazed structure. The vessels are filled with special finned tubing and in all some 200 miles of tubing will be needed for the twelve vessels.

Water enters the tubing at the bottom of the exchangers and flows upwards through two separate circuits, one a low-pressure and the other a high-pressure system, eventually being turned into superheated steam by the hot CO_2 gas circulating through the reactor.

Each of the twelve heat exchangers is a vertical pressure vessel of $1\frac{9}{16}$-in. thick plate, 19 ft diameter over the major portion of its length, with a 20 ft diameter section at the base. The overall height of each shell is 92 ft $4\frac{1}{2}$ in. and the weight 200 tons. A corrosion allowance on the plate thickness has been included.

Method of construction

The plates were first tested ultrasonically for flaws and laminations, and then normalized and flattened. Each individual plate was marked off, a double U-butt weld preparation machined on its edges and then rolled into the correct diameter. In a special drilling rig, the holes were drilled in the rolled plate for the thermal sleeves.

Each tier consisted of four plates which were assembled and tack welded into rings and then

continued on page 265

via a variable speed feeder and a conveyor to the blast furnace high line car, which will unload in the furnace bunkers.

The hot −¾-in. sinter returns will be carried by tray conveyor from the sinter screen to a quenching station. Here, a Schenk screen mounted over twin bunkers will divide the returns into two size fractions, +⅜ in. for bedding material and −⅜ in. for use as return sinter. The bedding fraction, after cooling, will pass to a surge hopper with a rotary feeder table from which it will be fed to the sinter machine. The return sinter fraction will be transferred to the return fines storage bins in the material storage building.

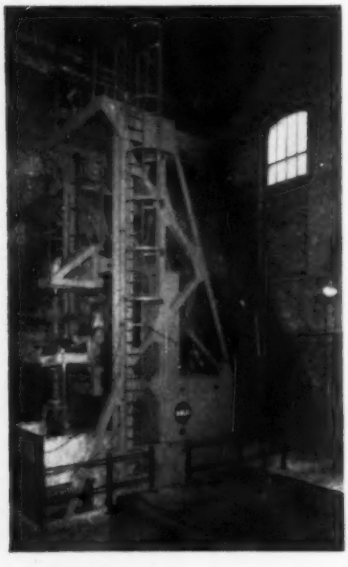
Dust extraction equipment is to be provided to handle the dust from the discharge end of the sinter machine and from the sinter screen, cooler and quenching station areas.

Hardening large rolls by induction heating

Some of the hardest work in industry is performed by rolling mills producing tinplate and other metal strips and sheets. The rolls which carry the load are made from special steel forgings, machined to fine limits and carefully heat treated for maximum endurance.

A new induction-heating equipment built by Birlec Ltd for William Beardmore & Co Ltd, Glasgow, and developed jointly by the two companies, makes an important contribution to the simplification and improved control of the tricky rehardening process. Induction heating has the great advantage of selectivity, permitting the work to be heated over a clearly defined area and to a predetermined depth below the surface, thus removing any risk of heating the roll necks or distorting their axial alignment.

The first Birlec machine of this kind is now in operation.



Birlec induction-hardening machine for hardening large rolls in operation at the Glasgow works of William Beardmore & Co Ltd

Designed to handle rolls up to 18 ft overall length and up to 32 in. dia, the machine supports the work vertically, between centres. The lower centre is motor driven to rotate the roll slowly during hardening. The structure which supports the upper centre in guides to provide for height adjustment, also carries slide-ways on which the heating head can be traversed over the length of the roll.

Heating of the roll is effected by high-frequency eddy currents induced in it by a water-cooled coil. A radiation pyrometer is provided to assist in controlling the temperature attained. Different coils can be interchanged easily so that the optimum clearance from the work, to give efficient energy transfer, can be maintained for any roll diameter. With the coil mounting, on the travelling head, is incorporated a water manifold arranged to flood the heated roll surface. Thus heating and quenching operations occur in succession, and the hardened zone spreads over the desired area as the heating head traverses the length of the roll.

High-frequency power is provided by a 400 kW motor alternater set, operating at 1,000 c/s. Unity power factor is assured by a bank of capacitors, the value of which can readily be adjusted by switching. Alternator voltage is closely governed, irrespective of load, by an automatic regulator of a highly sensitive electronic type which permits the heating power to be pre-set at any desired level and held constant throughout the operation.

Normal operating procedure involves pre-heating the roll at low power, with the quench water turned off, followed by a single hardening pass over the predetermined zone. Traversing speed and power level during hardening can be set as required to produce a hardened surface of appropriate depth for each type of roll.

With this machine a large roll can be preheated and hardened in about one hour. The hardness pattern can be controlled within close limits and distortion of the complete roll is negligible. Compared with the methods previously used, the process has great economic and technical advantages.

New offices for John Miles & Partners

Additional office space in the new Bucklersbury House in the City of London has been acquired by John Miles & Partners (London) Ltd to house the expanding consulting engineering and design staff. The present premises in Cannon Street, London, E C 4, will still be retained. The new offices on the sixth floor of the central Walbrook wing of the 13-storey building have been occupied since May 17.

Mr John Miles started his group of companies on exactly the same site as Bucklersbury House over 30 years ago, on the premises that his father, Mr T. V. Miles, had occupied since before the First World War. These premises were vacated in 1937 when the company moved to the nearby Granite House, and subsequently to 76 Cannon Street in 1946. The original offices in Walbrook were burnt out during the blitz.

Training young welders at Darlington

A new College of Further Education which has been recently opened at Darlington at a cost of about £180,000, includes facilities which will enable students to learn the latest techniques in welding.

A welding school has been built which can accommodate about 40 students. Courses are given in both oxy-acetylene welding and in arc welding. Oxy-acetylene equipment has been supplied to the school by British Oxygen Gases Ltd, and arc welding equipment by Quasi-Arc Ltd.

PEOPLE

THE INSTITUTE OF FUEL has elected an ' oilman,' **Mr T. C. Bailey,** to become president in October of this year. This will be only the second time that a member of the oil industry has occupied this office, the previous ' oilman ' president being Lord Cadman, who was president in 1935-36.

Mr Bailey was educated at Haberdashers' Aske's School, Cricklewood. His career since leaving school has been spent in the marketing side of the oil industry. He first entered the Fuel Oil Department of the Anglo-Mexican Petroleum Company, transferring in 1921 to Shell-Mex Ltd on the amalgamation of the Shell and Mexican interests, and then to Shell-Mex and B P Ltd on the further amalgamation with the British Petroleum Co Ltd in 1932.

For many years he devoted his attention to the application of fuel oil to industrial furnaces and during World War II was seconded to the Petroleum Board to play a leading part in developing the use of creosote pitch mixtures as fuel. After the war he was closely concerned with the development of oil-fired open hearth steel furnaces. In 1954 he was appointed sales manager (Industrial Fuels) of Shell-Mex and B P Ltd.

He joined the Institute in 1938 and was elected a Fellow in 1947. He has served on council since 1951 and became a vice-president in 1957.

Vice-Admiral Sir Frank Mason, K C B, M I MECH E, M I MAR E, has been appointed to succeed Sir Andrew McCance, F R S, as chairman of the Mechanical Engineering Research Board.

Sir Andrew McCance, D L, LL D, M I MECH E, F R S, who retires from the chairmanship of the Board, has had a long association with the Department of Scientific and Industrial Research. He was a member of the D S I R Advisory Council from 1942 to 1947 and in 1948 was elected a member of the Mechanical Engineering Research Board, of which he became chairman in 1952. Sir Andrew is distinguished for his work in the steel industry and particularly for his applications of physical chemistry to the processes of steel making and was elected to Fellowship of the Royal Society in 1943.

Admiral Mason, who is a director of Metal Industries Ltd and H. W. Kearns & Co Ltd, and consultant to the management of Metropolitan-Vickers Electrical Co Ltd, was, before his retirement from the Royal Navy in 1957, Engineer-in-Chief of the Fleet.

He entered the Royal Navy in 1918 as a Special Entry Cadet. In 1921 he elected to specialize in naval engineering and underwent courses at the Royal Naval College, Greenwich, and the Royal Naval Engineering College, Keyham. He later studied ordnance engineering and as a Commander (E) was appointed to H M S *Excellent*, the first engineer officer to fill a staff appointment in this famous establishment. In 1943 he was appointed Fleet Gunnery Engineer Officer, Home Fleet, and in 1944 was promoted to the rank of Captain (E) and went to the Department of the Director of Naval Ordnance where he helped in the planning of the Pacific war. He was Chief Gunnery Engineer Officer and Deputy Director of Naval Ordnance from 1947 to 1948, and in 1949 was the first engineer officer to pass through the Imperial Defence College. He was promoted to the rank of Rear Admiral (E) in 1950 and appointed Deputy Engineer-in-Chief of the Fleet. He attained the rank of Vice-Admiral (E) in 1953 upon his appointment as Engineer-in-Chief of the Fleet.

The United Steel Companies Ltd announces that **Lt-Cdr G. W. Wells,** D L, at present managing director (engineering works), has been appointed managing director (production) responsible to the general managing director, Mr A. J. Peech. Commander Wells will continue to hold the position of general manager of Appleby-Frodingham Steel Co, Scunthorpe, a branch of United Steel.

Following this appointment, **Mr A. Jackson** will relinquish his position as general works manager of Appleby-Frodingham as soon as possible in order to take up a new appointment as technical adviser on steelmaking for United Steel, responsible to Lt-Cdr Wells. He will retain his directorship of Appleby-Frodingham, but will become technical director of that company. Mr Jackson will also join the boards of the other three steelmaking companies in the group—Steel, Peech & Tozer, Samuel Fox & Co Ltd, and Workington Iron and Steel Co.

Mr T. W. Ruffle, F I M, has left the E N V Engineering Co Ltd. After some weeks in the U S A he will be setting up a British office for Ipsen Industries Inc of Rockford, Illinois. This will establish sales and service facilities here for the Ipsen automatic atmosphere heat-treatment furnaces and accessories, atmosphere generators

Mr T. W. Ruffle

and atmosphere control instruments, which are now available on the European market.

Mr J. D. Joy will relinquish his position of general works manager at Samuel Fox on August 31 and will move to Appleby-Frodingham as a director and general works manager with a view to becoming deputy general manager on January 1, 1959.

Thomas F. W. Jackson has been appointed chairman and managing director of Union Carbide Ltd in succession to W. B. H. Gallwey who died last December.

Mr Jackson, an Australian, was born n Sydney in. 1913 and was educated at the Scots College in Sydney. In taking over Union Carbide Ltd in this country, Mr Jackson heads a producing and marketing organization which handles ferro alloys and electro metallurgical products, chemicals, barium getters and valve components. The company is also concerned in polyethylene production with the new £4 million polyethylene-producing unit at Grangemouth, Scotland, and also with the construction of a major petrochemicals plant which is to be built at Fawley at a cost of £4 million. This latter unit is expected to be in production next year.

Mr Jackson is also a director of Union Carbide's affiliated companies, Gemec Ltd (chairman and managing), Bakelite Ltd and British Acheson Electrodes Ltd.

NEW PLANT

Universal Shaft-hardening Unit

For the first time in Britain, a shaft-hardening machine with all the facilities required for general purpose production is available from Radio Heaters Ltd, Eastheath Avenue, Wokingham, Berks. The machine is demonstrated progressively hardening eight bands on automobile rocker shafts. The shafts are rotated and moved slowly through the heating inductor for surface hardening. As soon as each ban is hardened, the shafts move rapidly forward to the next band. The two forward speeds and the reverse speed are all individually adjustable.

The unit will accept shafts up to 4 ft long and can be fitted with induction generators of any frequency of power output. It can be used for hardening right up to end flanges.

Electric Furnace Elements

A new non-metallic element which makes electrical heating of furnaces both economic and highly convenient has been developed by the Morgan Crucible Co Ltd. The new element, Crusilite, can be utilized in all temperature ranges up to 1,500°C. Furnaces covering the higher temperature in this range, *e g* drop-stamping and forging, can only meet the temperature and atmospheric requirements effectively by the use of silicon carbide elements. Until comparatively recent times Britain has been dependent on imported elements.

Crusilite is a one-piece, robust, silicon carbide tube, produced by a new method which uses a spiral as the hot zone. There are no joints between hot and cold zones, and therefore a common source of failure in other elements of this type does not exist. It ages at a much lower rate compared with similar elements, and therefore has a correspondingly lower replacement rate, and needs a reserve voltage of only 40%.

When replacements are necessary, the method is simple. Power is switched off, the element removed, new ones inserted and the power is switched on again. It is not necessary to dismantle the furnace and the replacement can be effected without even waiting for the furnace to cool.

Crusilite is manufactured in a large range of sizes and resistance values to cover the electrical conditions most frequently met in common practice.

In order to demonstrate this form of heating, a small Crusilite slot-type forge furnace is installed at the Midland Electricity Industrial Development Centre, Dudley, Worcs. This furnace is designed to heat billets to a temperature of 1,250°C at the rate of 130 lb/h.

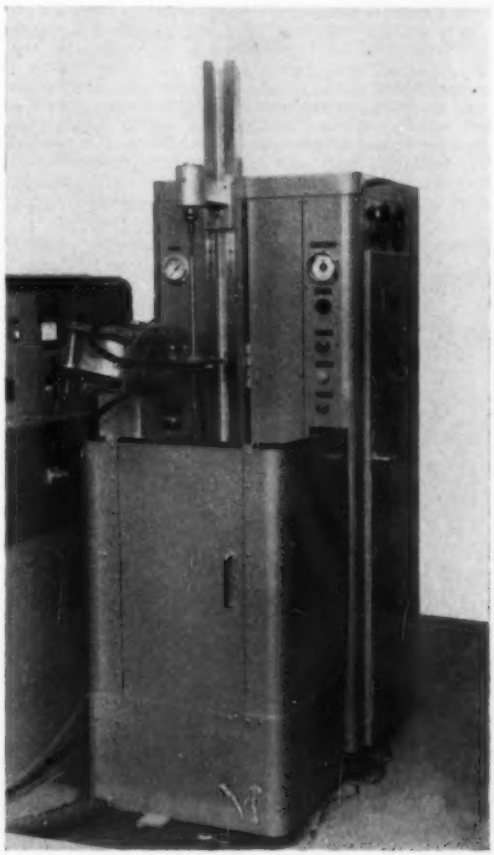
High-pressure Welding and Cutting

New equipment for welding and cutting, the Clyde high-pressure welding and cutting set, is being manufactured by D. S. Baddeley Engineering Co Ltd, 43-45 York Street, Glasgow. The blowpipe can be used only with dissolved acetylene from a cylinder or acetylene from a high-pressure generator or booster. To weld different thickness of material from $\frac{1}{32}$ to $\frac{3}{8}$ in, the operator has only to change the nozzle, but so as to enable the operator to keep further away from the heat when the larger nozzles are used a long head tube is supplied with the set. The mixing chamber permits the use of moderate pressures of oxygen and acetylene. The chief aim in the design of the shank has been to provide a light, well-balanced and comfortable blowpipe on which the controls have been conveniently placed in front of the operator. The handle tube of the shank is of milled brass which enables a flow of air to pass between it and the operator's hand, thus having an advantageous cooling effect.

From past experience this blowpipe has been designed to combine lightness with a strength to withstand considerable abuse. By care in the design of the mixing chamber a flame is produced that is proof against flash-back under the most exacting conditions.

The blowpipe is converted for cutting by the simple expedient of removing the welding head and attaching the cutting heads.

The nozzles normally supplied with the cutting heads will make very clean cuts of thicknesses from $\frac{3}{8}$ to 3 in. The control of the cutting oxygen is by means of a lever, conveniently placed for thumb operation; it is depressed while cutting and is self-closing when released, which avoids waste of oxygen if the blowpipe is laid aside while moving work into a more convenient position.



1 *'Radyne' universal shaft-hardening unit*

The gold medal of the Institution of Mining and Metallurgy for 1957 has been awarded to **Dr John Fairfield Thompson,** B S, PH D, in recognition of his distinguished services to metallurgical science, research and practice, with special reference to the nickel industry.

Dr Thompson was born at Portland, Maine, in 1881. He graduated at the Columbia University School of Mines with the B S degree in 1903, followed by the Ph D in 1906.

He began his long association with the International Nickel Co of Canada Ltd in 1906 as a metallurgist in their Orford works, investigating the potentialities of monel. He was placed in charge of all research and technical activities on monel and malleable nickel and made head of all field and outside plant operations. Dr Thompson established the first technical department of the company. As manager of operations in 1921 he supervised the construction and initial operations of the company's Huntingdon works, West Virginia, founded for the production of non-ferrous alloys.

In 1928 Dr Thompson became assistant to the president of INCO, and joined the board of directors in 1931. He became vice-president in 1932, executive vice-president in 1936, and president in 1949. In 1951 he was made chairman of the board of directors while continuing as president. He relinquished the presidency in 1952, but remains chairman and chief officer of the company. He is also chairman of the executive committee and a member of the advisory committee.

Dr Thompson was awarded the Thomas Egleston Medal of Columbia University Engineering School Alumni Association in 1944 for ' distinguished engineering achievements,' and in 1958 was presented with the American Institute of Mining, Metallurgical and Petroleum Engineers Rand Medal for ' distinguished achievement in mining administration.' He is a past president of the American Society for Testing Materials and also of the Mining and Metallurgical Society of America; he is an honorary member of the Institute of Metals, and a Commander of the Order of the White Rose, Finland.

Mr J. Hammond has been appointed deputy chief engineer of Samuel Fox & Co Ltd, Stocksbridge, near Sheffield, a subsidiary of the United Steel Companies Ltd. In this new position he will combine his present responsibilities as works engineer with those of assisting the chief engineer in the control of the overall engineering organization at the Stocksbridge works. Mr Hammond joined the company in 1945 to take charge of the engineering workshops and was appointed works engineer last year.

Mr R. H. Cooke has been appointed a director and general manager of Research and Control Instruments Ltd. Mr Cooke, who is well known in instrument circles, played a prominent part in organizing the British exhibit at the first ' Atoms for Peace ' conference in Geneva and serves on the committee of the nucleonics section of the Scientific Instrument Manufacturers' Association (SIMA). Having been associated for many years with non-destructive testing in industry, he is also a founder member of the Society of Non-Destructive Testing (SONDE).

Mr Thomas Johnston, C H, LL D, J P, F E I S, chairman of the North of Scotland Hydro-Electric Board, has been appointed president of the British Electrical Development Association in succession to Viscount Chandos.

As chief executive, Chemicals Division, British Oxygen, **Dr R. F. Goldstein,** in addition to being managing director of British Oxygen Chemicals Ltd, is now also managing director of Carbide Industries Ltd and a director of Odda Smelteverk.

Mr R. D. Watson, manager of the Lancashire District of British Oxygen Gases Ltd, has been elected as chairman of the Manchester and District Branch of the Institute of Welding for the year.

Mr E. E. Pheasey, M B E, M I B E, has been appointed works director of Thompson Bros (Bilston) Ltd, of Bradley Engineering Works, Bilston, Staffs.

OBITUARY

The death is announced of Mr A. H. Waine, aged 57 years, a director of Hadfields Ltd and managing director of the subsidiary company, Hadfields Forgings Ltd. Mr Waine was on a business tour of Germany, Holland and Belgium. In Brussels he was taken ill suddenly and died on May 4, 1958. He had been with Hadfields Ltd for over 40 years.

Mr Waine was born in Sheffield in 1901 and received his early education at Dronfield Grammar School. He continued his studies at Sheffield University where he gained the Associateship in Metallurgy and the Associateship in Engineering. He was awarded the Mappin Medal in 1930. In 1945, when he was manager of the heat-treatment departments at both Hecla and East Hecla Works, he became a local director of Hadfield Ltd. During 1948 he was invited to join the board of Hadfields Foundry & Engineering Co Ltd, at the same time acting as the technical manager of that company. He was elected to the board of Hadfields Ltd in 1950.

Mr A. H. Waine

Some of his many interests called for specialist knowledge and experience and one of these was steel supplies for ordnance. He served on several Government committees which were formed during the last war to deal with technical aspects of these materials and supplies, and was chairman of a regional committee and a subcommittee for armour-piercing projectiles from 1943 until its dissolution in 1950.

In addition to his other activities, Mr Waine devoted many years to the successful development and manufacture of hardened steel rolls. In cold-rolling industries he was well known not only at home but in Europe, North America and South Africa. He had travelled extensively, making many friends who appreciated his expert knowledge as well as a lively and attractive personality.

Mr Waine was a Fellow of the Institution of Metallurgists, an Associate of the Institute of Mechanical Engineers, a member of the Iron and Steel Institute, and a member of the Sheffield Society of Engineers and Metallurgists.

Heat exchanger

concluded from page 258

moved to the welding gantry where the internal and external longitudinal welds were made. All welds were examined by radiography and finally stress relieved.

The thermal sleeves were then welded into position. To prove the weld in this case, as it was not possible to use x-ray, a halogen gas test was put on to each sleeve to check for leaks.

The dished ends consisted of eight segments pressed to shape, here again double U-weld preparation was used. These were fitted to a jig and then welded by hand into a complete end. Reinforcing rings, outlets and flanges were finally welded into position. These again were x-rayed. In the case of the bottom dished end, the skirt plate was then welded on and the whole unit stress relieved at 630° C.

Testing procedure

As each section of four tiers was completed, these were finally welded together, the dished ends added and the vessels welded up complete.

The next operation was stress relieving. After being completely lagged, the whole of the vessel was brought up to a temperature of 630° C using internally suspended radiant electric heaters. After the vessel had cooled down and was stripped, the thermal sleeves were capped and an air test put on the vessel to check for leaks before the hydrostatic test. The vessel was then tested to a pressure of 270 lb/sq in.

On completion of the water test, the inside of the vessel and internal fittings were completely shot-blasted and the boiler sealed up in a water-tight condition. The inside was coated with colloidal graphite.

British engineering display in Canada

In conjunction with the Board of Trade, the Birmingham Engineering Centre is organizing a substantial British engineering exhibit at the National Industrial Production Show of Canada to be held in Toronto in May, 1959. This exhibition, one of the leading specialist industrial shows in Canada, is held every two years and receives widespread support from Canadian, American, European and British firms.

The Board of Trade's decision to mount a prestige display and the joining of forces with the Birmingham Engineering Centre to organize a separate British participation is an outcome of the Government's desire to exploit all possible means of expanding trade with Canada.

Classified Advertisements

FIFTEEN WORDS for 7/6d. (minimum charge) and 4d. per word thereafter. Box number 2/6d., including postage of replies. Situations Wanted 2d. per word.

Replies addressed to Box Numbers are to be sent, clearly marked, to Metal Treatment and Drop Forging, John Adam House, John Adam Street, London, W.C.2.

SITUATIONS VACANT

GILLETTE INDUSTRIES LIMITED
Isleworth, Middlesex
require
A QUALIFIED METALLURGIST

The successful candidate will be between 23 and 30 years of age, and will have had some experience of the metallurgy of non-ferrous metals, with further experience in operations such as hot stamping, pressing, machining, and general allied engineering processes. His duties will involve the investigation of problems arising out of current manufacturing methods, and the quality control of raw materials including rod and strip brass and aluminium.

Benefits include life insurance, contributory provident and non-contributory pension schemes. Applications in writing, which will be treated with strictest confidence, should give full details of age, education, experience, and salary required, and should be addressed to:

The Personnel Controller,
Gillette Industries Ltd.,
Great West Road,
Isleworth, Middlesex.

Quoting EAS/44.

SITUATIONS VACANT—continued

CHIEF METALLURGIST required for early appointment with a leading firm of gear specialists. Duties will include the control of a well-equipped laboratory, advice on materials and processes, and technical responsibility for a large heat-treatment shop equipped with gas carburising plant. Wide experience of heat treatment is essential and experience of engineering and machine shop practice very desirable. This position will carry a salary well into four figures and only men who can justify this salary level need apply. Write brief particulars of essential qualifications and experience, stating age and present salary to The Secretary, E.N.V. Engineering Co. Ltd., Hythe Road, London, N.W.10.

MACHINERY WANTED

WANTED. One only, Electric Furnace suitable for operating at temperatures up to 1,000° C., complete with all relative controls for use on 400-volt, 3-phase, 50-cycle supply. When submitting your offers kindly give full details of dimensions, etc., and mark for the attention of the Chief Engineer, The Chillington Tool Co., Ltd., P.O. Box 45, Wolverhampton.

MACHINERY FOR SALE

'EFCO Continuous Wire' Mesh Belt Conveyor Furnace, unused, suitable for bright annealing, etc., complete with inert gas generator and control gear. Box E C 105, METAL TREATMENT AND DROP FORGING.

Electrodes for Gouging and Piercing

The English Electric Co. Ltd., Clayton-le-Moors, Accrington, has introduced a new type of electrode for cutting grooves, gouging, piercing or removing surplus metal, and equally effective on all steels, cast iron and non-ferrous metals. These electrodes, known as 'Groovees,' can be used with ordinary a.c. or d.c. welding plant without additional equipment such as oxygen or air supplies. They leave a clean, scale-free surface that requires no further preparation before re-welding. As the electrodes contain a steel wire core, there is no chance of carbon pick-up.

For cutting grooves, the electrode is held at an angle to the work surface, pointing in the direction of travel. After an arc is struck, the electrode is moved rapidly along the line to be gouged. The force of the arc cuts the groove and removes the molten metal, giving a clean bright finish. For gouging out defects in castings a series of overlapping grooves are cut in alternate directions, making it possible to remove a defect of considerable depth. When piercing holes or removing rivets, the electrode is held perpendicular to the workpiece, the arc struck and held until the metal flows, and then the electrode moved into the molten pool.

Gas chromatography

THERE ARE TODAY several ways of monitoring continuous industrial processes. The best known is the monitoring of *p*H, which is a kind of acidity control in liquids in chemical production, in water purification and in waste-water control. Other methods include the composition control of gas streams or streams of liquids. This can be done by means of gas analysers which include those of the infra-red type and gas chromatographs. These instruments and a number of others were recently demonstrated by Dr. H. Right, head of Beckman Instruments G m b H, and Beckman Instruments Inc, U S A, at Winston Electronics Ltd, Shepperton, Middlesex.

2 *Beckman industrial gas chromatograph*

The gas chromatography method of analysis is relatively new, it being only in the last few years that the necessary instruments for analysis have been produced. The method involves the use of a tube of some material, *e g* copper, of ¼ in dia, filled with an absorptive material such as silica gel, charcoal or aluminium oxide. A stream of carrier gas is passed through the tube, to which the filling material is inert. The sample is then introduced and is carried through the column of filling material by the carrier gas.

The sample to be analysed is a mixture of various components and, according to their affinity to the filling material, they have different retention times in the column. Consequently, there is separation, the various components leaving the column at different times. This is the simplest of methods and, by means of it, one is able to separate a great number of components included in the same sample.

Dew-point Meter

A precision instrument for the measurement of water vapour density and water vapour pressure, proportion of water vapour by volume and dew-points, is now being manufactured under contract in this country by C. F. Casella & Co. The instrument is suitable for testing in many chemical manufacturing processes, air-conditioning and refrigeration installations, and can be employed in the measurement of furnace atmospheres for bright annealing, carburising, carbo-nitriding and bright-hardening where the water-vapour content of the furnace atmosphere and the atmosphere delivered from the gas generators is of first importance.

The 'Alnor' dewpoint meter is a portable, self-contained instrument, manually operated and designed for the measurement of the water-vapour content of air or any other gas which has a dew-point within the range −80° F. to room temperature. It was developed originally by the Illinois Testing Laboratories Inc. of Chicago for the testing of gases that are relatively dry and therefore within the dew-point range where most other methods of measurement become difficult or impossible.

The apparatus operates on the principle that, if a gas is compressed and the pressure released, the consequent expansion results in a cooling effect. If the expansion is sudden, adiabatic conditions are approached so that the final temperature can be calculated. If the pressure used is such that the gas when expanded cools to a temperature at which the water vapour present begins to separate out as a fog or dew, then this temperature is the dew-point. By means of a built-in hand pump, a sample of the gas is drawn into the instrument and held in the observation chamber above atmospheric pressure. The temperature of the gas is then read and the pressure quickly released by depressing the operating valve. This also switches the lamp on, illuminating the chamber, and if the gas has cooled to dew-point due to its rapid expansion, a fog will be observed through the window. Even where there are 'no dust' conditions the radium foil incorporated produces ions to act as substitute nuclei around which the droplets can form.

The instrument improves on others in this field by eliminating imprecise methods of reading and measurement, by making coolants unnecessary, and by enabling readings to be taken away from the source of the gas. It can be used, within its range, for any gas which is non-corrosive to brass or copper. It is claimed that the instrument has been so designed that it can be operated accurately by semi-skilled personnel. The sale and distribution of the dew-pointer is being carried out by Electric Resistance Furnace Co. Ltd., Netherby, Queens Road, Weybridge, Surrey.

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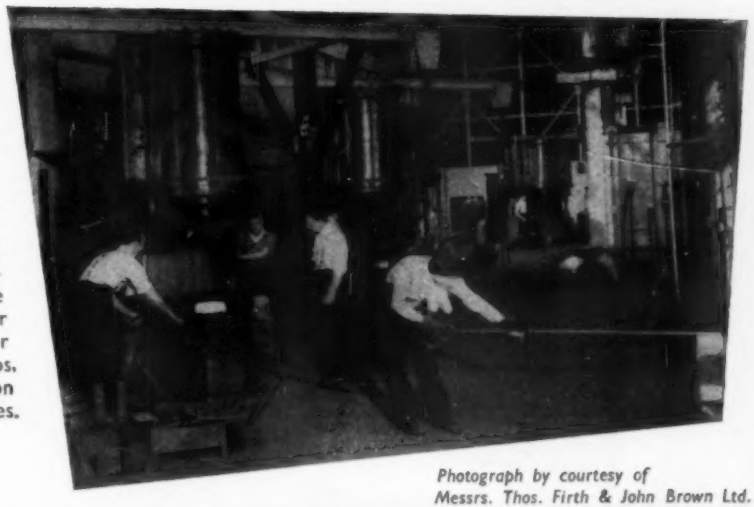

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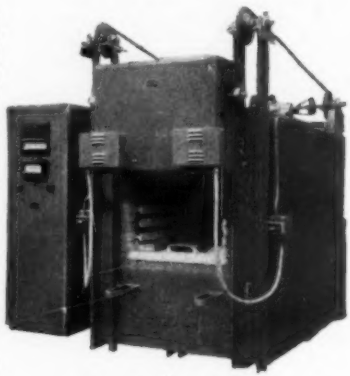

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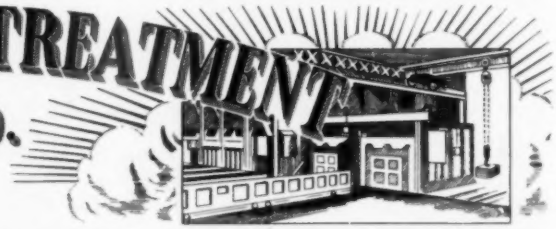

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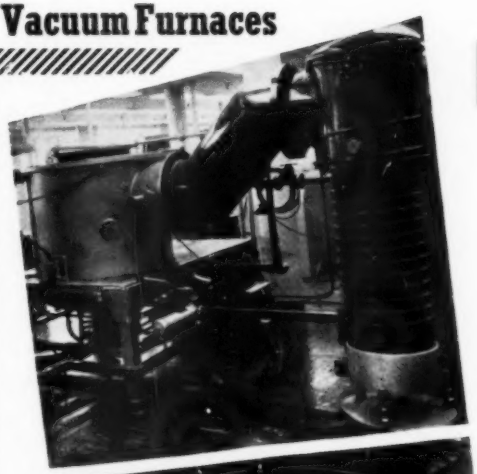

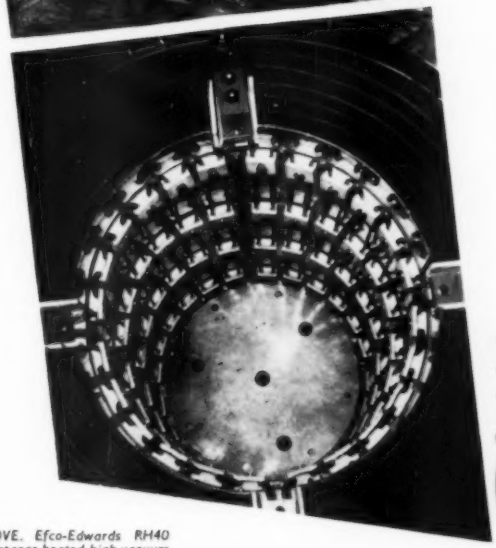

ABOVE. *Efco-Edwards RH40 resistance heated high vacuum brazing furnace. The "swan neck" vacuum connection was designed to overcome the low headroom. (Courtesy of Joseph Lucas, Limited.)*

BELOW. *A close-up of molybdenum heater showing the concentric radiation shields.*

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INDEX TO ADVERTISERS

	Page
Acheson Colloids Ltd.	5
Alldays & Onions Ltd.	—
Andrews, Thos., & Co. Ltd.	36
Annealers Ltd.	35
Baker Perkins Ltd.	—
Birlec Ltd.	13
Bottogas Ltd.	—
Brayshaw Furnaces & Tools Ltd.	—
Bretts Patent Lifter Co. Ltd.	—
Briggs Bros. & Co.	—
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Clyde Fuel Systems Ltd.	—
Coventry Machine Tool Works Ltd.	—
Cronite Foundry Co. Ltd. (The)	—
Delapena & Son Ltd.	19
Dohm Ltd.	—
Doncaster, Daniel, & Sons Ltd.	—
Dowson & Mason Ltd.	—
Dunford & Elliott (Sheffield) Ltd.	18
Efco-Edwards Vacuum Metallurgy Ltd.	37
Electric Resistance Furnace Co. Ltd.	14
Electro Heat Treatments Ltd.	33
Electroflo Meters Co. Ltd.	—
Elliott Brothers (London) Ltd.	—
English Electric Co. Ltd.	—
English Steel Corporation Ltd.	30
E.N.V. Engineering Co. Ltd.	33
Etchells, D., & Son Ltd.	16
Ether Ltd.	—
Eumuco (England) Ltd.	15
Expert Tool Heat Treatments Ltd.	—
Fel Electric Ltd.	36
Firth-Derihon Stampings Ltd.	10
Flame Hardeners Ltd.	35
Fuel Furnaces Ltd.	—
Gandy Ltd.	34
Gas Council	—
General Electric Co. Ltd.	8
General Refractories Ltd.	7
Gibbons Brothers Ltd.	26
Gibbons (Dudley) Ltd.	—
Granby, Paul, & Co.	21
G.W.B. Furnaces Ltd.	28
Hadfields Ltd.	—
Head Wrightson Machine Co. Ltd.	—
Hedin Ltd.	32
Herbert, A., Ltd.	—
Hills (West Bromwich) Ltd.	—
I.C.I. Ltd.	1
Incandescent Heat Co. Ltd. (The)	24
Integra, Leeds & Northrup Ltd.	—
International Furnace Equipment Co. Ltd.	—
Ivo Engineering & Construction Co. Ltd.	—
Johnson Foster, H., Ltd.	35
Kiveton Park Steel & Wire Works Ltd.	6
Lafarge Aluminous Cement Co. Ltd.	20, 23
Lee, Arthur, & Sons Ltd.	—
Manchester Furnaces Ltd.	—
Massey, B. & S., Ltd.	2
Mellowes & Co. Ltd.	33
Metal Heat Treatment Ltd.	34
Metalectric Furnaces Ltd.	27
Modern Furnaces & Stoves Ltd.	25
Morgan Refractories Ltd.	11
Morris, B. O., Ltd.	9
Newall, A. P., & Co. Ltd.	—
Nitralloy Ltd.	—
Nu-Way Heating Plants Ltd.	—
Plus Gas Co. Ltd.	—
Powder Metallurgy Ltd.	—
Priest Furnaces Ltd.	—
Schieldrop & Co. Ltd.	—
Shandon, E. R., Ltd.	—
Siemens-Schuckert (G.B.) Ltd.	—
Smethwick Drop Forgings Ltd.	—
Somers, Walter, Ltd.	38
Spear & Jackson Co. Ltd.	—
Special Steel Corporation Ltd.	32
Stein, John G., & Co. Ltd.	—
Thermic Equipment & Engineering Co. Ltd.	—
Thompson, Joseph, (Sheffield) Ltd.	—
Thompson L'Hospied & Co. Ltd.	—
Vacuum Industrial Applications Ltd.	—
Vaughan, Edgar, & Co. Ltd.	—
Ward, Thos. W., Ltd.	—
Wickman Ltd.	4
Wiggin & Co. Ltd.	22
Wild-Barfield Electric Furnaces Ltd.	3 & 12
Wilkins & Mitchell Ltd.	17
Wykeham, W., & Co. Ltd.	—

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